Differential Responses of Oat Varieties to 2, 4-D Amine and MCPA Amine

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DIFFERENTIAL RESPONSES OF OAT VARIETIES

TO 2,4-D AMINE AND MCPA AMINE

BY

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DIFFERENTIAL RESPONSES OF OAT VARIETIES TO 2,4-D AMINE AND MCPA AMINE

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

Weed control in oats (*Avena sativa* L.) is principly achieved by post emergence herbicide applications. The two most widely used being the amine salts of 2,4-D and MCPA (16). Both 2,4-D (2,4-dichlorophenoxy) acetic acid and MCPA (4-chloro-O-tolyl) oxy acetic acid belong to a class of compounds known as the phenoxys. Other compounds in this class include 2,4,5-T (2,4,5-trichlorophenoxy) acetic acid, 2,4-DB 4-(2,4-dichlorophenoxy) butyric acid, and the ester formulations of 2,4-D and MCPA (16). The phenoxys are auxin type growth regulators. The cause of death from phenoxy compounds is believed to be the physiological disfunction of the plant brought about by abnormal growth (10,16).

MCPA and 2,4-D have similar herbicidal properties, residual toxicity lengths and human toxicities (16). One area in which the chemicals are dissimilar, is in crop tolerance. Oats are more tolerant to MCPA than to 2,4-D (2,7,31). It has been proven oats are more susceptible to 2,4-D at certain growth stages than at others, and some varieties appear to be more susceptible to 2,4-D than others (2,18,25,29,31). Researchers have reported varietal differences in oats when treated with either 2,4-D ester or amine (2). The differences are usually much greater with the ester applications. It has also been theorized that varietal response to 2,4-D may be related to the genetic makeup of each variety (2).

The objectives of this study were to determine the response of eleven oat varieties to 2,4-D amine and MCPA amine. Also, to determine if varietal response to 2,4-D is related to the genetic makeup of the varieties.

LITERATURE REVIEW

South Dakota is a major oats producing state. In 1984 it ranked number one in the nation with a production of 86,800,000 bushels of oats (32). Of this, about 10-15% is sold to race horse feed packers and millers (13). Both of these industries want good quality, high test weight oats. To grow this high quality oat, a producer must implement a good weed control program. Of the 1.5 million acres of oats grown in South Dakota in 1984 (32), an estimated 40% use some type of chemical weed control.

The most widely used herbicide on oats is 2,4-D amine (16). In 1942 Zimmerman and Hitchcock first described the use of 2,4-D as a plant growth regulator (21). In 1943 it was discovered 2,4-D was capable of selectively killing certain plants (21). This discovery was essentially the beginning of the chemical weed control revolution.

The mode of action of 2,4-D involves three phases; a rapid induction phase (0 to 2 days) when ion absorption and photosynthesis are accelerated; a redistribution phase (2 to 7 days) when growth of the axis is accelerated at the expense of leaf tissue; a final senescence-collapse (7 to 10 days) (10). The chemical concentrates in rapidly growing young embryonic or meristematic tissues. These tissues are affected more than inactive or mature tissues (16).

Thus, the stage of development of the plant directly influences its susceptibility to 2,4-D. Plants treated during growth stages with high meristematic activity are generally most susceptible (1).

2,4-D may enter the plant through the roots or by foliar absorption (16). Two factors affecting the absorption and translocation of 2,4-D are temperature and humidity, increasing either generally results in increased penetration by 2,4-D (20). Pallas (20), using C^{14} labelled 2,4-D, found at lower humidities (34-48%), less 2,4-D was absorbed and translocated than at higher humidities (70-74%). Also, by increasing temperatures, absorption and translocation were increased. Clor et al. (3) using cotton seedlings, reported under normal conditions the translocation of 2,4-D was mainly downward to the roots with some movement via the phloem to the shoot tip and young leaves. However, when the plants were treated under very high humidity, the translocation pattern changed. The 2,4-D moved into the roots as well as mature and young leaves, indicating transport via phloem and xylem.

MCPA is nearly identical to 2,4-D in molecular formula and has similar herbicidal properties (16). However there are differences between the herbicides. Both chemicals effectively control wild mustard (Brassica kaber L.), lambsquarter (Chenopodium album L.), Russian pigweed (Axyris amarantoides L.), and ball mustard (Neslia paniculata L.) (9). However, MCPA gives better control of hemp nettle (Galeopsis tetrahit L.) than 2,4-D (9). MCPA is less effective at controlling Russian thistle (Salsola kali L.) and redroot pigweed (Amaranthus retroflexus L.) (9) along with several other broadleaf weeds and most larger weeds when used at low rates (9,31).

2,4-D may be used on a wide range of crops such as barley (Hordeum vulgare L.), corn (Zea mays L.), oats, rice (Oryza sativa L.), rye (Secale cereale L.), sorghum (Sorghum bicolor L.), sugarcane (Saccharum officinarum L.) and wheat (Triticum aestivum L.) as well as pastures and rangelands (1). Used in low concentrations it serves as a growth regulator to reduce fruit drop and increase fruit size (16). MCPA has been used for weed control in small grains, pastures, flax (Linum usitatissimum L.) and peas (Pisum sativum L.) (16). MCPA can also be used at low rates to control weeds in oats underseeded with a legume (31). MCPA is more expensive than 2,4-D and larger quantities are usually needed for good weed control (16). Some crops such as oats, are generally more tolerant to MCPA than 2,4-D (2,9,16,31), although there has been reported cases of MCPA causing injury (2,7). There are also differences between the ester and amine formulations of 2,4-D. While 2,4-D ester gives better weed control than 2,4-D amine, it also can result in more crop injury. In general, oats are more tolerant to 2,4-D amine than 2,4-D ester, however, 2,4-D amine can also cause injury to oats (2).

Many studies have indicated 2,4-D can cause injury to the crop when sprayed during certain growth stages. Besides herbicide rates, stage of growth is the most important single factor affecting 2,4-D injury (4). Olson et al. (19), studying the effect of 2,4-D on barley, found it to be most susceptible to 2,4-D treatment during two growth stages. The first is the early seedling stage when the plants are one to five inches tall (two-to-five leaf stage). This is the time period when the differentiation of the spike in the growing point takes place. The other susceptible growth period is from late boot up until heading. Johanson and Muzik (14) applied 2,4-D amine to six wheat varieties at several different growth stages. They too determined the seedling and early flowering stages to be most susceptible. Furthermore, they stated part of the decrease in yield may be a result of damage to the roots. 2,4-D stimulated cell division and differentiation of the lateral roots but inhibited elongation of those roots. Hoshaw and Gaurd (11) also found root abnormalities in wheat following application of 2,4-D.

While 2,4-D has been proven to adversely affect certain crops, it also affects varieties differently. Since there is so much genetic variability in small grain varieties, one would expect a considerable amount of variability in tolerance levels (22). Derscheid et al. (4), using three 2,4-D formulations at four growth stages, reported barley varieties responded differently to the applications of 2,4-D. He found some varieties to be much more susceptible than others. Price and Klingman (22), using twenty seven winter wheat varieties treated with two rates of 2,4-D amine reported results similar to Derscheid's barley study. Of the twenty seven varieties, three had no yield reductions by either treatment, eleven varieties had good tolerance, ten had yields reduced by the higher rate but were tolerant to the lower rate, and four varieties were susceptible to both rates of 2,4-D. This study indicates there are varying degrees of tolerance to 2,4-D. As stated before, this may be due to the large genetic variability in small grain varieties. However, small grains are not the only crop to have differential responses by varieties. Rossman and Staniforth (24) reported some inbred lines of corn to be more susceptible to 2,4-D than others. Elder (6) found a definite differential response in sorghum varieties. Also, some flax varieties are slightly more tolerant to 2,4-D than other varieties (29).

Oats is another crop which in the past has been found to respond differentially to 2,4-D at the varietal level. Using a butyl ester, an alkanol amine and a monohydrate sodium salt of 2,4-D, Derscheid et al. (5), looked at the varietal response of nine oat varieties. They reported a varying level of tolerance by the varieties. Some varieties had yield reductions of 15-20%. The butyl ester formulation was more toxic to the oats than were the salts. Similar results were reported by Arnold and Auch (2) using 2,4-D and MCPA on oat varieties. They reported significant differential varietal responses. Price and Klingman (22) sprayed oats with 0.58 kg/ha of 2,4-D amine during the early tillering stage of growth, and reported varietal differences in yield reductions.

It is evident 2,4-D can reduce yields of some crops and some varieties, but 2,4-D also causes other physiological and morphological changes. Derscheid et al. (5) looked at the effect of 2,4-D amine on yield components of oats. It was determined oat varieties having yield reductions also had a significant reduction in the number of seeds per panicle. With a reduction in the number of seeds per panicle, the average seed size tended to increase. This suggests the reduction in yield caused by 2,4-D treatment is a result of a reduction in seed numbers and not a result of smaller seeds. Yield in oats is closely associated with the number of seeds per panicle (5). 2,4-D also can cause a reduction in the number of spiklets per panicle in some oat varieties (2).

Tillering is another plant function affected by 2,4-D. Spraying with 2,4-D ester can increase the amount of tillering by an oat plant (2,5). However, even with an increase in the amount of tillering, yields may still be reduced (2).

Differential varietal responses are also evident in visual injury and plant malformities (2,5,8,16,18,22). Some of the more common injuries include tubular or onion-like leaves (2,5,8,18,22), multiple panicles, root distortions, partially blasted panicles, and clustered panicles (8,17,18). Depending on the severity of the plant injury, there may or may not be yield reductions.

While numerous studies have been done on 2,4-D and its affect on small grains, MCPA has been studied much less. There are still many unanswered questions about both MCPA and 2,4-D. Little is known about whether or not small grains can pass on 2,4-D susceptibility to following generations. The objectives of this study were: 1) determine whether oat varieties economically important to South Dakota gave a differential response to 2,4-D amine and MCPA amine treatments. 2) determine the effect of 2,4-D amine and MCPA amine on yield components, rust, number of tillers per meter and their correlation to yield. 3) determine the extent genetic factors influence the tolerance of oat varieties to 2,4-D amine and MCPA amine.

MATERIALS AND METHODS

Field studies were conducted in 1984 and 1985 on the Agronomy Farm at Brookings, South Dakota, the Northeast Research Station near Watertown, South Dakota and the Southeast Experiment Station near Centerville, South Dakota. The soil at the Brookings location was a Vienna silt loam. The Watertown plots were on a Brookings silty clay loam, and the Centerville location was an Egan silty clay loam. Soil analysis for the Watertown and Brookings locations in 1985 are found in Appendix 1.

Eleven varieties were used. Variety descriptions and pedigrees are shown in Table 1. In 1984, the varieties used were Burnett, Chief, Clintland 64, Garland, Lancer, Moore, Noble, Nodaway 70, Ogle and Porter. In 1985, the variety Kelly replaced Garland. The experimental design was a randomized complete block with four replications per treatment. Treatments consisted of 0, 0.28, 0.56 and 0.84 kg ai/ha of 2,4-D amine, and 0.56 kg ai/ha of MCPA amine. The plots were kept weed free by handweeding.

In each year, 100 kg/ha of seed was drilled to a depth of 3.8 cm (1.5 inches). Each plot consisted of two rows, 0.3 m (one foot) apart and 4.27 m (14 feet) long. Every sixth plot was planted to the variety Stout as a border to prevent overlapping of spray treatments. After

Table 1. Description and pedigrees of oat varieties treated with 2,4-D amine and MCPA amine.

Variety	Maturity Classification	Grain Color	Pedigree
Burnett	Medium	Ivory	Victoria//Hajira/Banner/3/Colorado
Chief	Medium	Yellow	Clintland 64/Garland
Clintland 64	Medium	Yellow	Clintland*5/5/Landhafer/3/Mindo//Hajira/ Joanette/4/Andrew/6/Clintland//Grey/Algerian
Garland	Medium	Yellow	Clintland/3/Garry//Hawkeye/Victoria
Kelly	Early	White	Dal/Nodaway 70
Lancer	Medium	White	Neal/Clintland 59
Moore	Late	White	Lodi/B65B1286//Lodi
Noble	Medium	Yellow	complex (improved Tippecanoe involving 12 lines)
Nodaway 70	Early	White	Columbia/Marion/4/Victoria//Hajira/Banner/3 /Victoria/Hajira//Roxton
Ogle	Medium	Yellow	Brave//Tyler/Egdolon 23
Porter	Late	White	CI7684 selection//(Putnam 5/Minn. 313)2/ Albion/3/Stout

the oats had headed, the rows were shortened to 3.66 m (12 feet). At Watertown in 1984 and 1985, herbicides were applied when the oats were in the three-to-four leaf stage. However, in 1985, at the Centerville and Brookings locations, five days of continuous high winds prevented spraying until the oats were in the 5½-to-6 leaf stage. Therefore, the Watertown plots sprayed during the three-to-four leaf stage are discussed seperately from the Centerville and Brookings locations which were treated while the oats were in the 5½-to-6 leaf stage. When determining leaf stages, each leaf of the main culm was counted as one leaf. Leaves were not counted until the collar of the leaf was visible without tearing the plant. Tillers were not counted as a leaf. Conditions at time of spraying, along with dates of planting are shown in appendix 2. A bicycle-mounted sprayer was used to apply both herbicides. The herbicides were applied in 187 l/ha of water at 26×10^4 Pa. (38 psi). 8002 Tee Jet nozzles were used at a height of 45.7 cm (18 inches) above the tops of the oat plants.

Plant height was taken by estimating the average height of the entire plot. This was accomplished by holding a straight bamboo stick across the plot at the estimated average height, and recording the height measurement where the bamboo touched a calibrated stick.

The heading date was also taken. When one-half of the panicles in the plot were one-half emerged, the plot was considered headed and the date recorded. To determine the effect of 2,4-D amine and MCPA amine on straw strength, percent lodging was evaluated. The percent of the plants in the plot which were lodged was recorded. The lodging readings were taken after heading. Rust notes were taken to see if the herbicides have an effect on crown rust. The Cobb's modified scale was used. The scale aids in determining the percent of the leaf area which is covered by rust pustules. The rust readings were taken before the lower leaves of the oat plant began to yellow and while the rust was still in the uridiospore stage.

After the oat plants were fully mature and the panicles dry, two 0.3 m (one foot) subsamples were cut from each plot. The two subsamples came from different rows and opposite ends of the plot. From these, yield components and the number of seed bearing panicles were determined. Ten panicles per subsample (twenty heads per plot) were individually threshed in a head thresher. The seeds were then hand counted and weighed to determine the number and weight of the seeds in each panicle. The average seed weight was determined by dividing the weight of the seeds by the number of seeds. The 1000 seed weight was calculated by multiplying the average seed weight of the plot by 1000. In 1984 the number of grain producing panicles per 0.3 m (one foot) subsample were counted. In 1985, the grain producing panicles in a one meter length of row from each plot were counted.

The plots were harvested using a Suzue binder and a midsized Vogel thresher. After cutting and binding a plot with the Suzue binder, the bundles were tagged and laid across the stubble to dry. Once dry, the bundles were threshed in the Vogel thresher. The grain was weighed for yield, cleaned and test weighed. The Statistical Analysis System (SAS) package was used to perform the statistical analysis. Means of herbicide rates were separated with the Waller-Duncan test.

RESULTS AND DISCUSSION

The oat varieties exhibited different tolerances to 2,4-D amine and MCPA amine at all locations, in both years. However in 1984, due to improper spraying at Centerville, and herbicide carryover at Brookings, the data of these locations was discarded.

YIELD

2,4-D amine

Grain yield is the most important parameter in this study. Treatment with 2,4-D at the three-to-four leaf stage resulted in differential response in yield. 2,4-D amine at the 0.28 kg ai/ha rate did not significantly reduce grain yields of any variety. However, the 0.56 kg ai/ha rate significantly reduced the yield of the variety Lancer by 7 and 9% in 1984 and 1985 respectively (Table 2). No other variety had statistically significant yield reductions at this rate. At the 0.84 kg ai/ha rate of 2,4-D amine, the yields of Garland, Kelly, Lancer and Nodaway 70 were significantly reduced. While the yield of some varieties was reduced by 2,4-D, other varieties responded to treatment with yields equal to or slightly greater than the controls. The varieties Moore and Porter both consistantly had 2,4-D treated plots yielding slightly higher than the control plots (Appendix 3). The differences were

Table 2. Percent yield reductions of oat varieties treated with 2,4-D amine and MCPA amine. Reductions are expressed as a percent of the control.

	kg/ha	Burnett %	Chief %	Clintland 64 %	Garland %	Kelly %
				Watertown (1984)		
	0.28	+1	+1	+6	-6	--
2,4-D	0.56	+2	+8	+6	-2	--
	0.84	-6	0	0	-9	--
MCPA	0.56	+3	+5	+5	-3	--
				Watertown (1985)		
	0.28	-7	+3	0	--	-4
2,4-D	0.56	+1	0	-13	--	-5
	0.84	-5	+4	-12	--	-7
MCPA	0.56	-5	+5	-5	--	-7
				Centerville (1985)		
	0.28	-23	-14	-10	--	-24
2,4-D	0.56	-32	-24	-21	--	-23
	0.84	-32	-27	-32	--	-29
MCPA	0.56	+6	-8	-4	--	-12
				Brookings (1985)		
	0.28	-11	-11	-4	--	-18
2,4-D	0.56	-24	-21	-22	--	-26
	0.84	-31	-25	-24	--	-32
MCPA	0.56	-2	-4	+1	--	-7

Table 2 (con't). Percent yield reductions of oat varieties treated with 2,4-D amine and MCPA amine. Reductions are expressed as a percent of the control.

	rate kg/ha	Lancer %	Moore %	Noble %	Nodaway 70[1] %	Ogle %	Porter %
				Watertown (1984)			
	0.28	-6	+1	+3	--	0	+5
2,4-D	0.56	-7	+6	-2	--	+1	+4
	0.84	-8	+5	-6	--	+2	0
MCPA	0.56	-5	+4	-7	--	0	-13
				Watertown (1985)			
	0.28	-3	+1	+2	-1	-2	+3
2,4-D	0.56	-9	+1	-2	+2	+2	+2
	0.84	-13	+1	-4	-7	0	+1
MCPA	0.56	-9	+1	+4	-3	+1	-6
				Centerville (1985)			
	0.28	-10	0	-6	-20	0	-6
2,4-D	0.56	-13	0	-10	-24	+1	-13
	0.84	-25	-3	-21	-29	-8	-20
MCPA	0.56	-3	+9	-3	-8	0	-6
				Brookings (1985)			
	0.28	-8	-9	-5	-7	-3	+6
2,4-D	0.56	-19	-11	-18	-20	-9	0
	0.84	-26	-14	-34	-29	-13	-5
MCPA	0.56	-3	-5	-9	+9	-4	+5

1 the Nodaway 70 plots at Watertown in 1984 were damaged by ground squirrels.

nonsignificant, yet they indicate Moore and Porter are tolerant to 2,4-D. The yield of Ogle also tended to increase slightly or remain equal to the control. The varieties in this study can be classified by their tolerance to 2,4-D amine. Lancer would be susceptible to 2,4-D as indicated by its significant reduction in yield at the 0.56 kg ai/ha rate. Garland, Kelly and Nodaway 70 are slightly susceptible as their yields were significantly reduced at the 0.84 kg ai/ha rate. Burnett, Chief, Clintland 64 and Noble are somewhat tolerant since 2,4-D reduced their yields slightly but not significantly. Moore, Porter and Ogle are tolerant to 2,4-D amine due to yields which equalled or surpassed the controls for all rates. This classification differs from an earlier study which rated Garland as having good tolerance to 2,4-D (28). However, our study agrees with a study by Stritzke (27), who reported Clintland 64 as having intermediate tolerance. These reductions are the result of spraying 2,4-D amine when the oats are in the recommended three-to-four leaf stage of development. Treatment during this stage usually gives better weed control (32), and will result in less injury than if the oats are sprayed during the five-to-six leaf stage (27,28). According to Stritzke (27), who applied 2,4-D ester to several oat varieties, the most susceptible stage of development is the five-to-six leaf stage (27). At the five leaf stage, the panicle of most varieties is about one inch above ground level within the plant. A dissected plant will have empty glumes beginning to appear (9). The undeveloped panicle would be in an area of high meristematic activity. 2,4-D concentrates in areas of high meristematic activity (1), thus treatment during this time may result in increased injury.

In this study, treatment during the 5½-to-6 leaf stage resulted in significantly higher yield losses by some varieties while the yields of other varieties were reduced very little if at all (Appendix 4). In general, those varieties which were classified as tolerant to 2,4-D treatment during the three-to-four leaf stage, were also somewhat tolerant to treatment at the 5½-to-6 leaf stage. The yields of Moore and Ogle were reduced by the 0.56 and 0.84 kg ai/ha treatments of 2,4-D at Brookings. However, the yields of Moore and Ogle at Centerville, along with Porter at Brookings were not significantly reduced by any rate of 2,4-D. Clintland 64 at the 0.28 kg ai/ha rate was the only other variety which did not experience a significant yield reduction. Those varieties which were classified as having intermediate to fair tolerance or as being susceptible to 2,4-D at the three-to-four leaf stage, were generally very susceptible when treated at the

5½-to-6 leaf stage. Lancer, which was the only variety to have its yield significantly reduced by the 0.56 kg ai/ha rate at the three-to-four leaf stage application, had a 16% yield reduction at the 5½-to-6 leaf stage treatment (Table 2). The yields of Burnett, Chief, Clintland 64, Kelly and Nodaway 70 treated with the 0.56 kg ai/ha rate had losses ranging from 22 to 29%. Excluding Ogle, Moore and Porter, the yield reductions of all other varieties, when treated with the 0.84 kg ai/ha rate of 2,4-D, ranged from 26 to 31%. As the rate of 2,4-D increased, the yields of all varieties decreased. A comparison of the yield reductions of nine varieties at all locations across the three rates of 2,4-D, are in Figures 1,2 and 3.

MCPA

While there are studies reporting differential varietal responses of oats to 2,4-D amine, few studies have found MCPA to cause yield reductions in oats. Arnold and Auch (2), working with MCPA on the oat variety Garland saw significant visual injury consisting of discolored tubular leaves. However, they reported no significant yield reductions. Everett (7), studied the effect of several formulations of MCPA on an early and a late maturing oat variety. The oats were treated when six inches tall (leaf stage was not indicated). He reported serious

Figure 1. The effect of three rates of 2,4-D amine on the yields of Lancer, Noble and Chief in four trials. Reductions are expressed as a percent of the controls.

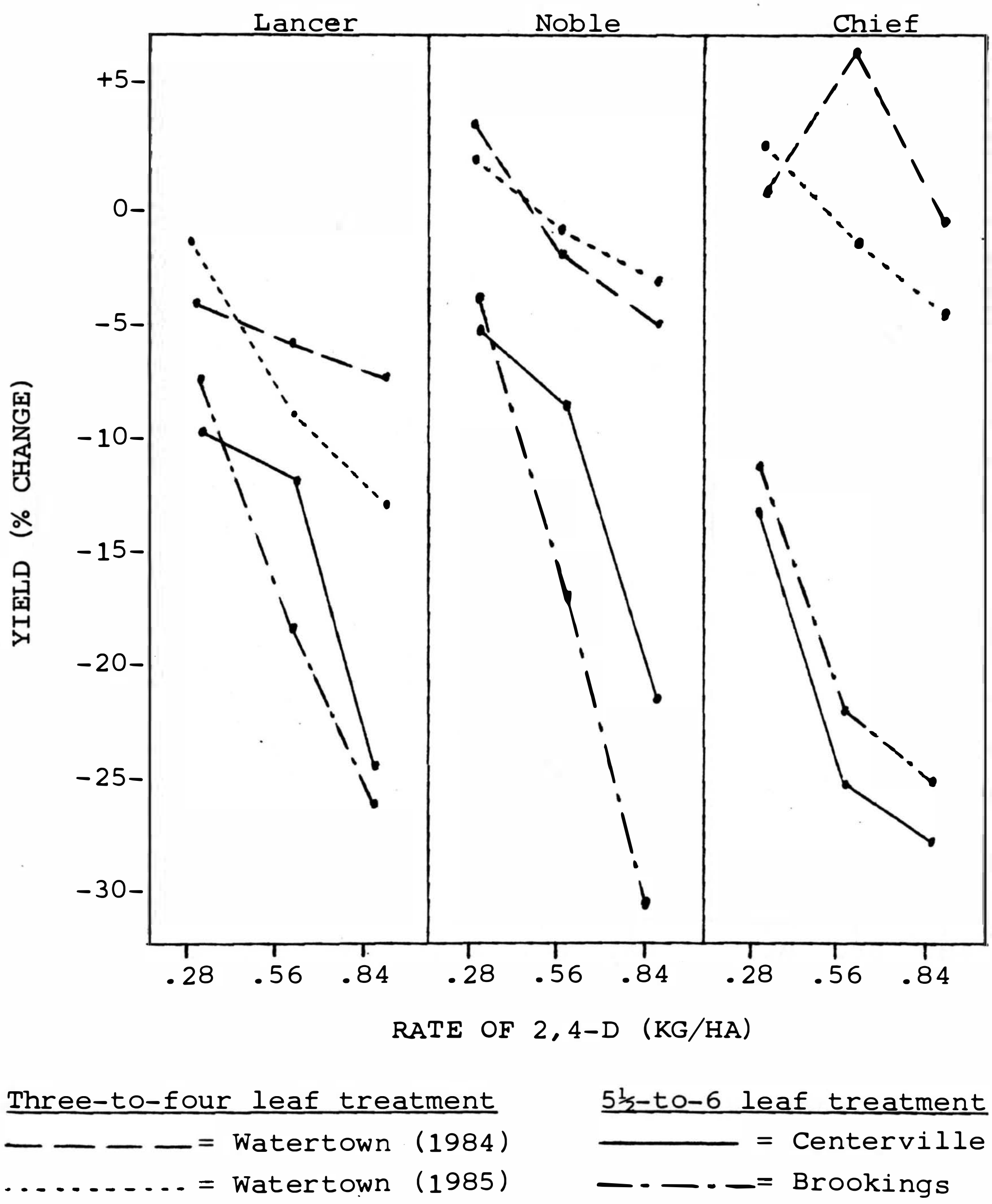


Figure 2. The effect of three rates of 2,4-D amine on the yields of Nodaway 70, Kelly and Moore in four trials. Reductions are expressed as a percent of the controls.

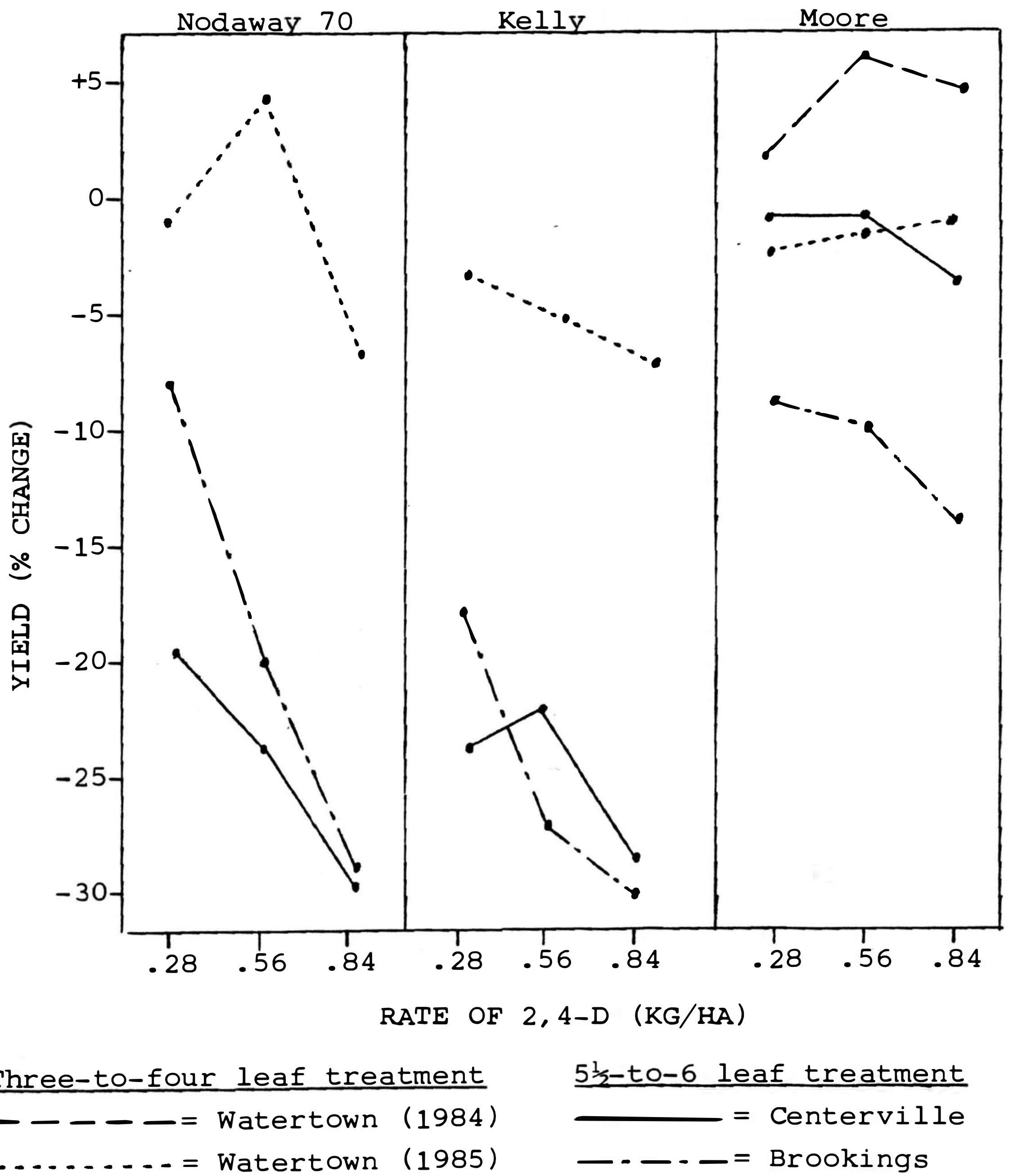
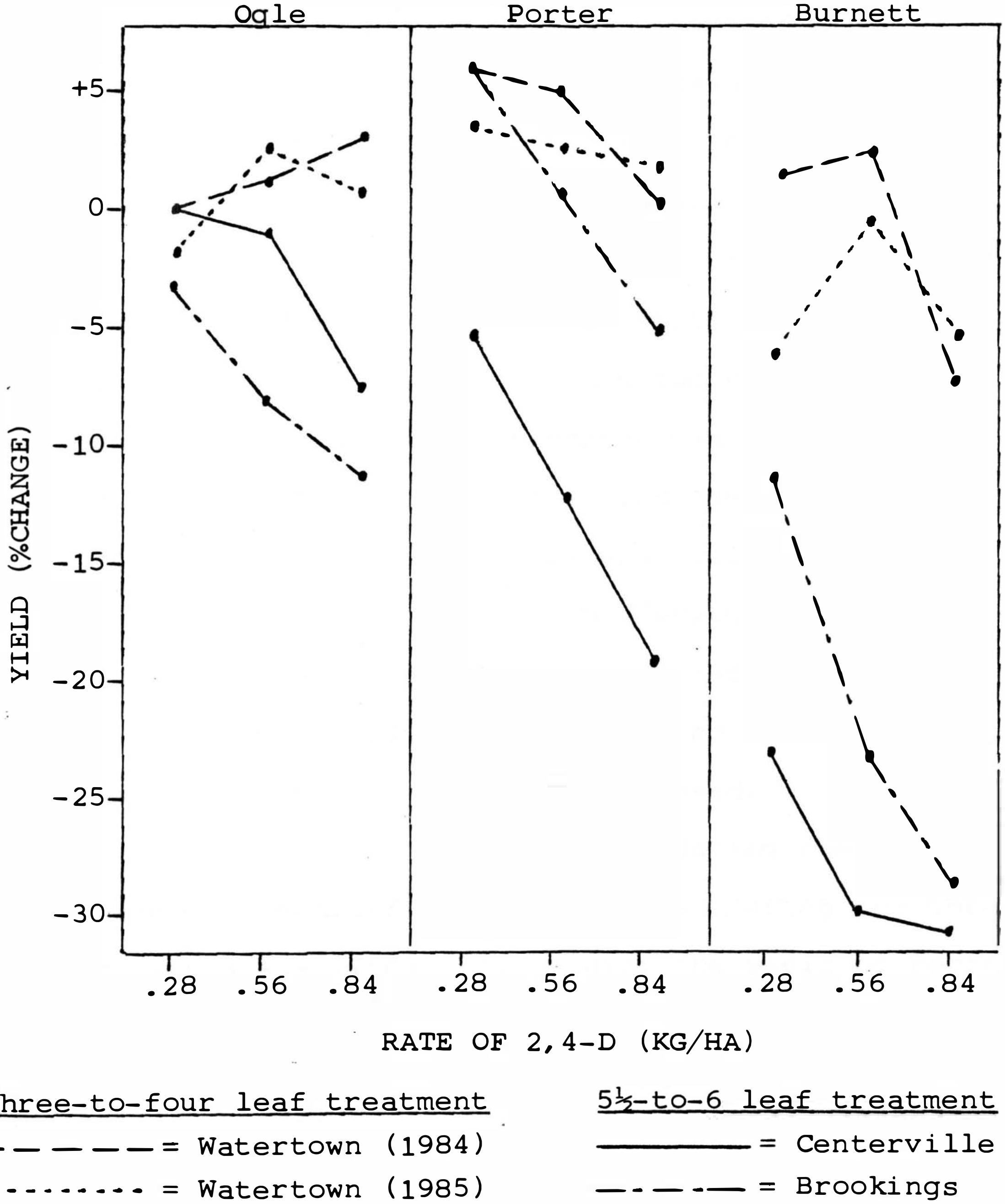


Figure 3. The effect of three rates of 2,4-D amine on the yields of Ogle, Porter and Burnett in four trials. Reductions are expressed as a percent of the controls.



yield reductions in the early maturing variety when treated with an amine formulation of MCPA. The late maturing oat experienced no yield reduction. He theorized that in the early maturing variety, morphological development of the flower proceeded faster than the height of the plants so the florets were in a susceptible stage.

In this study, when treated at the three-to-four leaf stage with MCPA, all varieties except three tended to have yields equal to or greater than the controls (Table 2 and Appendix 3). The yield of Porter was significantly reduced by MCPA amine in both 1984 and 1985. In 1985, Kelly and Lancer also had significant yield reductions. These results differ somewhat from Everett's. Everett reported only the early maturing variety had a yield reduction, while in this study the yields of an early, a medium and a late maturing variety were decreased.

The results of MCPA treatment during the 5½-to-6 leaf stage were similar to those treated during the three-to-four leaf stage (Table 2). Again, the yield of Porter was significantly reduced, however only at Centerville and not at Brookings. Kelly had significant yield reductions by MCPA at both locations. All other varieties had no significant differences.

An important comparison to make, from an oat producers standpoint, is one between the recommended rates of 2,4-D and MCPA. In this study, there were no significant differences in yield between the 0.56 kg ai/ha rates of 2,4-D and MCPA when applied during the three-to-four leaf stage, with one exception, Porter. In both years the yield of Porter was significantly higher when sprayed with 2,4-D as compared to MCPA. However, when comparing the 0.56 kg ai/ha rates of 2,4-D and MCPA at the 5½-to-6 leaf stage, MCPA caused far fewer yield reductions than 2,4-D. In this study, all varieties with the exception of Ogle, had significantly higher yields when treated during the 5½-to-6 leaf stage with MCPA as compared to 2,4-D. This is due to the chemical directly affecting the oat plant and not due to the weed controlling capabilities of each chemical.

Past studies have indicated the risk of crop injury from 2,4-D is usually greater when growing conditions are near ideal (1,31). This was not the case in this study. The oat growing season at the Watertown location was near ideal in 1984 and somewhat dry in most of 1985. While the yield levels were different, the trends and percent yield reductions did not vary much from year to year. Temperature and precipitation data for the 1984 and 1985 growing seasons are given in Appendix 5.

Test Weight and Lodging

2,4-D amine

Next to yield, test weight is second in importance in oat production, particularly oats grown for the race horse feed market. In this study, 2,4-D sprayed on oats during the recommended three-to-four leaf stage did not directly reduce the test weight of any variety. This agrees with Aldrich (1), who reported 2,4-D amine had no effect on the seed weight of oats. Derscheid (5) et al. also reported salt formulations of 2,4-D did not reduce seed weight.

While it is evident 2,4-D amine does not directly reduce test weight, it reduced test weight indirectly through increased lodging in this study. 2,4-D caused a sharp increase in percent lodging at all locations where any lodging existed. Only Watertown in 1985 had no lodged plants. Percent lodging was significantly correlated (r^2= .66) with varietal height. The trend for all varieties was an increase in the percent lodging as the rate of 2,4-D increased. Table 3 gives the percent lodging of all varieties at three locations. The lodging may be due to a reduction in straw strength and/or possible root injury caused by 2,4-D. 2,4-D has been reported to inhibit lateral root elongation of oats, corn (30) and wheat (14). Derscheid (4) et al., reported lodging as a result of

Table 3. Percent lodging for oat varieties treated with 2,4-D amine and MCPA amine. The Watertown location was treated while the oats were in the three-to-four leaf stage, while oats at Brookings and Centerville were in the 5½-to-6 leaf stage.

	Watertown (1984) Rate of 2,4-D (kg/ha)				MCPA (kg/ha)
	control	0.28	0.56	0.84	0.56
Burnett	33	45	75	76	45
Chief	14	14	29	44	0
Clintland 64	7	11	55	61	17
Garland	17	19	41	30	8
Lancer	0	0	23	21	5
Moore	8	34	66	84	12
Noble	0	0	10	16	0
Nodaway 70	0	6	9	31	5
Ogle	0	0	0	14	0
Porter	9	31	42	59	6
Average	9	16	35	43	10
		Centerville (1985)			
Burnett	12	76	75	73	48
Chief	11	30	45	41	8
Clintland 64	15	30	50	46	34
Kelly	12	51	57	46	52
Lancer	0	20	22	37	11
Moore	8	29	39	40	8
Noble	6	13	16	23	5
Nodaway 70	7	56	52	32	16
Ogle	0	6	22	35	0
Porter	9	49	50	68	27
Average	9	36	43	44	21
		Brookings (1985)			
Burnett	33	64	64	74	22
Chief	18	11	22	13	11
Clintland 64	21	8	13	27	15
Kelly	25	25	52	24	10
Lancer	7	5	10	12	5
Moore	11	10	35	20	0
Noble	0	0	0	17	0
Nodaway 70	14	21	32	27	9
Ogle	0	0	9	7	0
Porter	40	24	47	59	6
Average	17	17	29	28	9

using 2,4-D on barley.

In this study, there was a highly significant, negative correlation (r^2=-.51) between percent lodging and test weight. If lodging is increased, test weight is decreased. Each variety treated in the three-to-four leaf stage had a reduction in test weight when there was lodging, regardless of the effect 2,4-D had on yield. At the Watertown location in 1985, there were significant yield reductions, yet there was no lodging by any variety, and there were virtually no reductions in test weight. Conversely, in 1984 at the same location, with similar yield reductions, there was lodging by all varieties and nearly all test weights were reduced. Test weights in 1984 were not equal to the controls unless there was no lodging by that variety at that rate of 2,4-D. Table 4 gives a comparison of test weights and lodging for all varieties. Lodging may reduce the test weight of oats by a combined effect of constricting the vascular bundles, and decreasing leaf surface area exposed to sunlight. Figure 4 compares the test weight and percent lodging of Chief and Noble in 1984 and 1985 at Watertown for three rates of 2,4-D.

The test weight reductions of oats sprayed with 2,4-D during the 5½-to-6 leaf stage were not significantly different from those in the three-to-four leaf treatment

Table 4. Percent lodging and test weight of oat varieties treated with 2,4-D amine and MCPA amine at Watertown in 1984 and 1985. Oats were in the three-to-four leaf stage when treated.

1984

	rate (kg/ha)	Burnett %[1]	Burnett TW[2]	Chief %	Chief TW	Clintland 64 %	Clintland 64 TW	Garland[3] %	Garland[3] TW	Kelly[4] %	Kelly[4] TW
	0	33	36.3	14	35.0	7	36.5	17	36.3	--	----
2,4-D	0.28	45	35.5	14	34.7	11	35.8	19	36.2	--	----
	0.56	75	34.3	29	36.7	55	35.0	41	34.9	--	----
	0.84	76	34.0	44	33.1	61	34.5	30	34.9	--	----
MCPA	0.56	45	34.9	0	34.5	17	35.3	8	35.9	--	----

1985

	rate (kg/ha)	Burnett %	Burnett TW	Chief %	Chief TW	Clintland 64 %	Clintland 64 TW	Garland %	Garland TW	Kelly %	Kelly TW
	0	0	33.8	0	33.2	0	33.1	--	----	0	35.5
2,4-D	0.28	0	34.0	0	33.0	0	32.6	--	----	0	35.3
	0.56	0	34.0	0	33.0	0	33.1	--	----	0	35.6
	0.84	0	33.7	0	33.0	0	32.6	--	----	0	35.1
MCPA	0.56	0	33.5	0	32.8	0	32.8	--	----	0	35.1

1 percent lodging
2 test weight (pounds per bushel)
3 Garland was in the study in 1984 only
4 Kelly was in the study in 1985 only

Table 4 (con't). Percent lodging and test weight of oat varieties treated with 2,4-D amine and MCPA amine at Watertown in 1984 and 1985. Oats were in the three-to-four leaf stage when treated.

1984

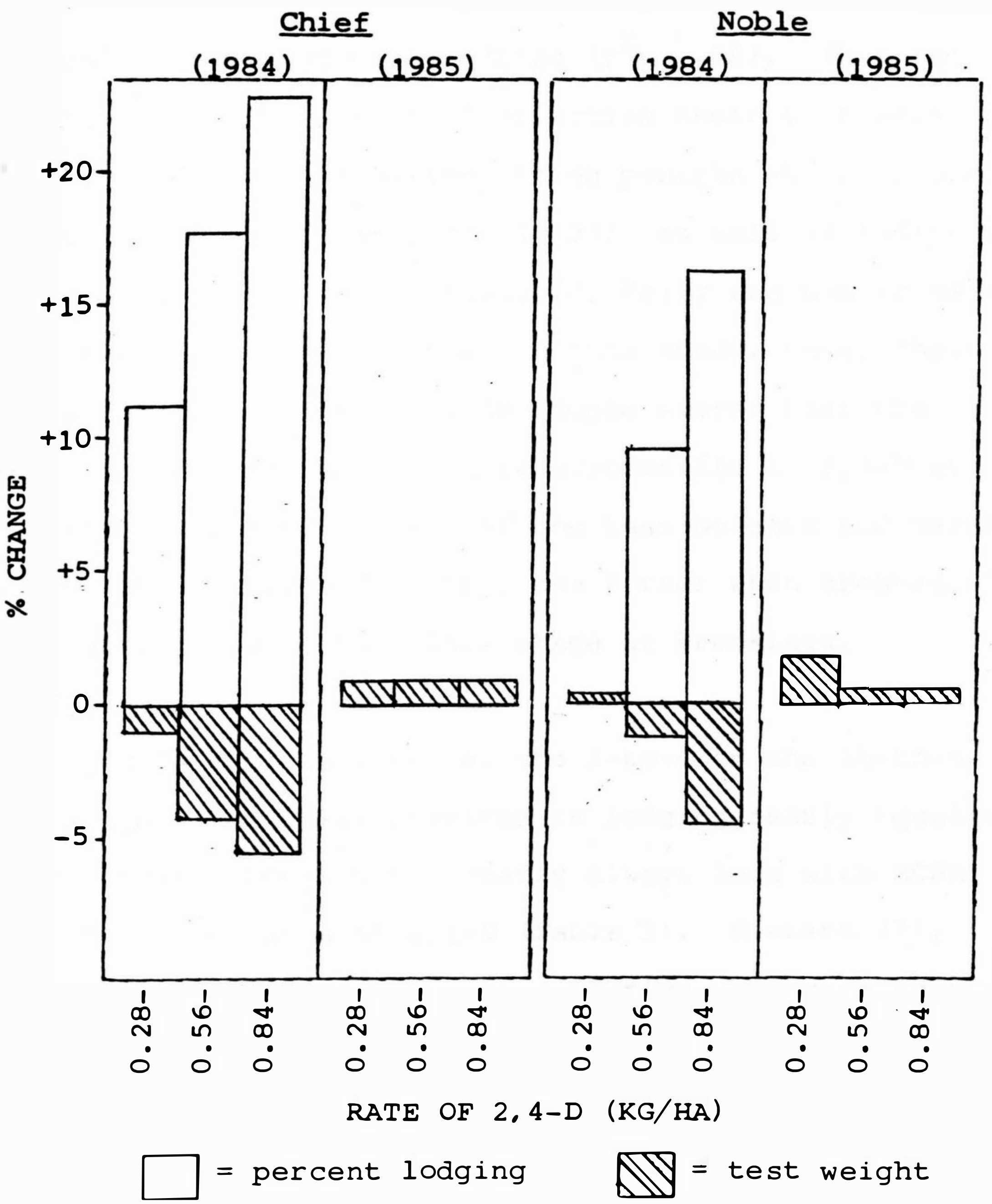
	rate (kg/ha)	Lancer %[1]	Lancer TW[2]	Moore %	Moore TW	Noble %	Noble TW	Nodaway 70 %	Nodaway 70 TW	Ogle %	Ogle TW	Porter %	Porter TW
	0	0	35.6	8	38.2	0	35.3	0	37.0	0	34.0	9	37.4
2,4-D	0.28	0	34.5	34	37.8	0	35.4	6	36.9	0	33.7	31	36.8
	0.56	23	34.2	66	36.6	10	34.8	9	35.8	0	33.9	42	36.3
	0.84	21	33.7	84	37.2	16	33.8	31	35.3	14	33.5	59	35.6
MCPA	0.56	5	34.2	12	37.4	0	35.4	5	36.7	0	33.5	6	37.1

1985

	rate (kg/ha)	Lancer %	Lancer TW	Moore %	Moore TW	Noble %	Noble TW	Nodaway 70 %	Nodaway 70 TW	Ogle %	Ogle TW	Porter %	Porter TW
	0	0	32.5	0	31.9	0	32.7	0	33.9	0	29.4	0	32.1
2,4-D	0.28	0	33.0	0	31.9	0	33.2	0	34.6	0	29.4	0	32.6
	0.56	0	33.0	0	31.5	0	32.6	0	35.4	0	30.0	0	31.6
	0.84	0	33.2	0	31.3	0	32.9	0	34.6	0	29.6	0	32.4
MCPA	0.56	0	32.1	0	31.6	0	32.6	0	34.0	0	28.5	0	31.0

1 lodging (%)
2 test weight (pounds per bushel)

Figure 4. Test weight and percent lodging of Chief and Noble at Watertown in 1984 and 1985. 2,4-D amine was applied when the oats were in the three-to-four leaf stage of development. Results are expressed as a percent of the control.

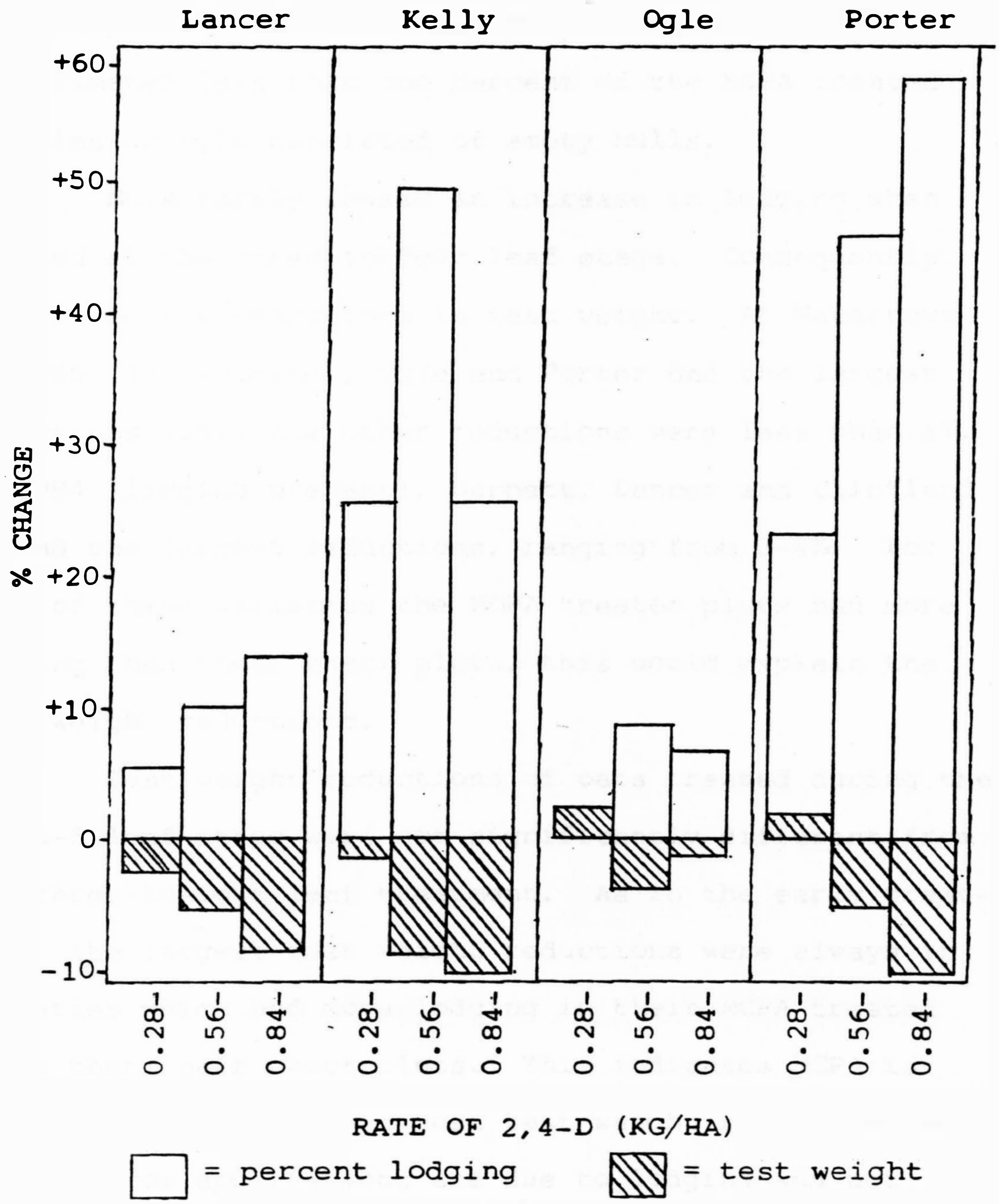


(Appendix 6). For all but three varieties, the test weight reductions were again significantly correlated (r^2= -.46) with the increase in lodging caused by 2,4-D. The test weight reductions of Nodaway 70, Kelly and Lancer were not as highly correlated with lodging (r^2= -.36). This is possibly due to the chemical affecting their test weights directly by injuring the developing panicle which is present by the five or six leaf stage (9,23), as well as indirectly via increased lodging. Nodaway 70, Kelly and Lancer have the three earliest maturities in this study, thus, their growing points are probably developed sooner than the other varieties, making them the most susceptible to 2,4-D at this stage. Figure 5 compares the test weights and percent lodging of Lancer, Kelly, Ogle and Porter when treated with 2,4-D during the 5½-to-6 leaf stage at Brookings.

<u>MCPA amine</u>

MCPA applications (at the 3-to-4 or the 5½-to-6 leaf stages) generally resulted in lodging nearly equal to the controls. Lodging was nearly always less with MCPA than the three rates of 2,4-D (Table 3). Everett (7), working with MCPA amine on oat varieties, reported severe effects on the variety Fundy. Apparently kernels failed to form although glumes and hulls were present. This was a result of treatment when the oat plants were six inches tall; no indication as to leaf stage was given. The

Figure 5. Test weight and percent lodging of Lancer, Kelly, Ogle and Porter when treated with 2,4-D amine during the 5½-to-6 leaf stage at Brookings in 1985. Results are expressed as a percent of the control.



effects of MCPA in this study were not as severe as Everetts', however it should be noted, during the processing of the subsamples a few panicles of Ogle, from MCPA treated plots, contained only glumes and empty hulls. It is estimated less than one percent of the MCPA treated panicles of Ogle consisted of empty hulls.

MCPA rarely caused an increase in lodging when treated at the three-to-four leaf stage. Consequently, there were few reductions in test weight. At Watertown in 1985 (no lodging), Ogle and Porter had the largest reductions (3%), all other reductions were less than 1%. In 1984 (lodging present), Burnett, Lancer and Clintland 64 had the largest reductions, ranging from 3-4%. For each of these varieties the MCPA treated plots had more lodging than their check plots, this would explain the test weight reductions.

Test weight reductions of oats treated during the 5½-to-6 leaf stage were not significantly different from the three-to-four leaf treatment. As in the early treatment, the largest test weight reductions were always in varieties which had more lodging in their MCPA treated plots than their check plots. This indicates MCPA is similar to 2,4-D in that most test weight reductions resulting from applications are due to lodging and not direct herbicidal action.

Plant Height, Rust and Heading Date

2,4-D amine and MCPA amine treatments on oats had very little effect on plant height. On the average, 2,4-D treated oats were slightly taller than the untreated oats, while MCPA treated plots were slightly shorter than the controls. Differences for both herbicides were nonsignificant (Appendix 7). These results agree with Arnold and Auch (2), who reported no significant differences in plant height of oats treated with 2,4-D amine or MCPA amine.

There are very few studies dealing with the effect of 2,4-D on oat rust. Ibrahim (12) did greenhouse studies to determine the effect of 2,4-D on oat stem rust, mainly its effect on the germination of uridiospores and on development of rust infections on susceptible and resistant oat varieties. He reported the effect of 2,4-D on stem rust is not enough to change a susceptible variety into a resistant one. In our study, 2,4-D and MCPA treatments did not significantly change the percent rust of any variety (Appendix 8).

The date of heading for all varieties was unaffected by 2,4-D or MCPA (Appendix 9). Heading dates were only taken at Brookings in 1985.

Yield Components

2,4-D amine

The yield reductions of oats sprayed with 2,4-D amine during the three-to-four leaf stage were primarily due to a reduction in the number of seeds per panicle. This agrees with Derscheid (5) et. al, who reported yield reductions in oats treated with 2,4-D ester were due to a reduction in the number of seeds per panicle. Kent and Hutchinson (15), reported 2,4-D amine reduced the number of grains produced by an oat plant. In both of these studies, a reduction in seeds per panicle was accompanied by an increase in 1000 seed weight. This was also reported by Arnold and Auch (2) as they found oat plants treated with high rates of 2,4-D amine had greater seed weights than untreated controls. The reduction in the number of seeds per panicle may favor the growth of the remaining seeds (15).

In our study, the analysis of variance of seeds per panicle indicated a highly significant F value for variety by treatment interaction. Thus, varieties were analyzed and discussed seperately. Trends are also discussed. Only Moore at Watertown in 1985, did not have a reduction in the number of seeds per panicle for any rate of 2,4-D. Kelly in 1985 and Garland in 1984 had seed numbers reduced only at the 0.84 kg/ha rate (Table 5).

Table 5. The number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine and MCPA amine at Watertown in 1984 and 1985. Treatments were applied while the oats were in the three-to-four leaf stage.

Watertown 1984

	rate (kg/ha)	Burnett seeds[1]	Burnett KW[2]	Chief seeds	Chief KW	Clintland 64 seeds	Clintland 64 KW	Garland seeds	Garland KW
	0	42	34.0	58	27.3	45	27.4	43	27.1
2,4-D	0.28	38	33.9	48	28.3	44	27.3	48	27.7
	0.56	35	34.6	48	28.7	46	27.7	43	26.9
	0.84	33	34.4	47	27.8	39	28.1	40	28.7
MCPA	0.56	41	31.6	51	27.5	48	27.1	43	27.7

Watertown 1985

	rate (kg/ha)	Burnett seeds	Burnett KW	Chief seeds	Chief KW	Clintland 64 seeds	Clintland 64 KW	Garland seeds	Garland KW
	0	41	22.9	51	19.7	56	19.5	--	----
2,4-D	0.28	39	22.4	49	20.3	46	19.5	--	----
	0.56	38	23.1	45	21.3	41	20.0	--	----
	0.84	40	23.0	39	21.4	41	21.3	--	----
MCPA	0.56	41	22.9	52	20.6	48	20.4	--	----

1 number of seeds per panicle
2 weight of 1000 kernels (gm)

Table 5 (con't). The number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine and MCPA amine at Watertown in 1984 and 1985. Treatments were applied while the oats were in the three-to-four leaf stage.

	rate	Kelly		Lancer		Moore		Noble	
	(kg/ha)	seeds[1]	KW[2]	seeds	KW	seeds	KW	seeds	KW
Watertown 1984									
	0	--	----	50	28.8	51	31.4	42	28.7
2,4-D	0.28	--	----	42	29.1	48	30.6	40	29.2
	0.56	--	----	44	28.8	45	31.1	42	28.4
	0.84	--	----	40	29.0	46	31.3	35	29.2
MCPA	0.56	--	----	44	28.4	45	31.6	41	28.7
Watertown 1985									
	0	40	21.1	43	20.0	51	19.6	38	20.9
2,4-D	0.28	41	22.4	42	20.0	52	21.0	35	20.6
	0.56	40	22.1	39	21.7	53	20.6	35	22.7
	0.84	36	21.8	38	20.7	56	20.8	31	23.9
MCPA	0.56	38	21.9	46	19.9	55	19.9	35	21.4

1 number of seeds per panicle
2 weight of 1000 kernels (gm)

Table 5 (con't). The number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine and MCPA amine at Watertown in 1984 and 1985. Treatments were applied while the oats were in the three-to-four leaf stage.

Watertown 1984

	rate (kg/ha)	Nodaway 70 seeds	Nodaway 70 KW	Ogle seeds	Ogle KW	Porter seeds	Porter KW
	0	33	32.0	45	32.0	49	33.1
2,4-D	0.28	32	32.1	44	32.5	45	32.7
	0.56	31	31.9	45	32.2	44	33.4
	0.84	28	32.2	42	31.6	45	32.3
MCPA	0.56	34	30.8	47	31.4	50	32.6

Watertown 1985

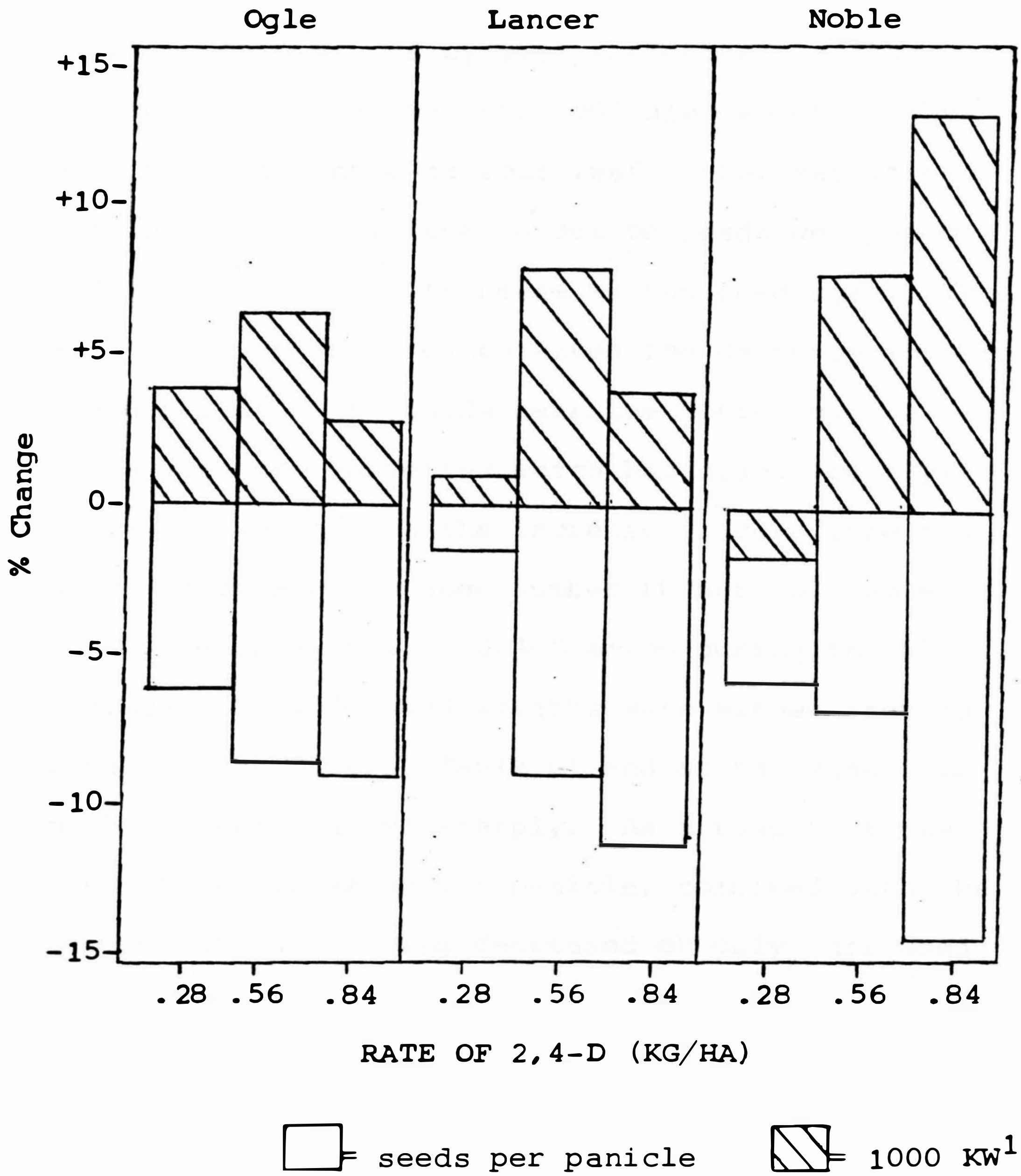
	rate (kg/ha)	Nodaway 70 seeds	Nodaway 70 KW	Ogle seeds	Ogle KW	Porter seeds	Porter KW
	0	43	22.8	56	20.1	51	21.1
2,4-D	0.28	38	22.2	53	20.9	51	21.3
	0.56	37	22.8	52	21.4	46	22.1
	0.84	40	21.7	51	20.6	48	21.1
MCPA	0.56	40	21.6	54	20.6	48	20.5

1 number of seeds per panicle
2 weight of 1000 kernels (gm)

All other varieties, in both years, had a reduction in seeds per panicle when treated with any rate of 2,4-D. This reduction was usually followed by an increase in seed size (Table 5). While there were no significant differences in 1000 seed weight, there were definite trends across the three rates of 2,4-D. Besides being affected by seed number reductions, it appears the 1000 seed weight is also affected by lodging as was test weight. At Watertown in 1985 (no lodging) if seed numbers decreased, 1000 seed weights increased (Figure 6). There was a highly significant, negative correlation (r^2= -.44) between seeds per panicle and 1000 seed weights when no lodging was present. However, at Watertown in 1984 (lodging present), if the number of seeds per panicle was reduced, the weight of the seeds either increased only slightly or were decreased. The seed size increase was almost always less when lodging was present. This is shown by the seeds per panicle and 1000 seed weight correlation. While remaining highly significant, it dropped from r^2= -.44 (no lodging) to r^2= -.28 (with lodging). While a reduction in seeds per panicle favors an increase in seed size, the effect of lodging on the filling of the seed prevented or reduced this increase.

A reduction in the number of seeds per panicle was also the main factor reducing yields of oats treated

Figure 6. Number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine during the 3-to-4 leaf stage in 1985 at Watertown. Results are expressed as a percent of the controls. (no lodging)



1 weight of 1000 kernels

during the 5½-to-6 leaf stage. Seed number reductions were significantly greater for most varieties when treated at these later stages (Table 6). This coincides with the larger decrease in yields by most varieties. Another factor affecting yields was the 1000 seed weight. When treated during the three-to-four leaf stage, varieties which had a reduction in the number of seeds per panicle generally experienced an increase in the seed size. This increase, to an extent, counteracted the decrease in seed number and resulted in yields near the controls. The exceptions were the varieties which had significant yield reductions, in which case the increase in seed size did not fully counteract the seed number reduction. However, when oats were sprayed with 2,4-D amine during the 5½-to-6 leaf stage, the 1000 seed weights were either reduced or increased very little (Table 6) and at the same time seed numbers were reduced sharply. As a result of the large reductions in seeds per panicle, combined with the 1000 seed weight also being decreased or only increased slightly, yields were reduced much more than during the three-to-four leaf treatment. As with test weight, the seed weight reductions may be a result of the chemical directly affecting the newly developing panicle which is present during the five-to-six leaf stage (9). The lodging which was present at both Brookings and

Table 6. The number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine and MCPA amine at Centerville and Brookings. Treatments were applied while the oats were in the 5½-to-6 leaf stage.

	rate (kg/ha)	Burnett seeds[1]	Burnett KW[2]	Chief seeds	Chief KW	Clintland 64 seeds	Clintland 64 KW	Kelly seeds	Kelly KW
Centerville 1985									
	0	44	26.2	50	25.7	52	22.3	39	27.1
2,4-D	0.28	32	29.1	48	24.3	40	24.6	34	25.2
	0.56	28	28.3	39	24.9	38	23.9	29	26.3
	0.84	30	26.7	37	25.0	35	24.2	28	25.6
MCPA	0.56	35	26.5	45	25.8	47	22.5	32	26.2
Brookings 1985									
	0	47	29.8	59	27.3	54	24.9	44	33.3
2,4-D	0.28	38	30.2	54	28.6	45	27.3	32	32.6
	0.56	33	28.6	48	26.7	41	27.6	26	30.9
	0.84	32	28.6	39	27.0	38	26.2	24	30.0
MCPA	0.56	42	31.2	58	27.2	49	26.7	35	33.1

1 number of seeds per panicle
2 weight of 1000 kernels (gm)

Table 6 (con't). The number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine and MCPA amine at Centerville and Brookings. Treatments were applied while the oats were in the 5½-to-6 leaf stage.

Centerville 1985

	rate (kg/ha)	Lancer seeds[1]	Lancer KW[2]	Moore seeds	Moore KW	Noble seeds	Noble KW	Nodaway 70 seeds	Nodaway 70 KW
	0	46	25.0	59	24.2	53	23.6	40	26.0
2,4-D	0.28	41	24.5	51	25.6	44	24.8	37	26.2
	0.56	36	24.8	49	25.0	44	24.8	30	27.8
	0.84	31	24.2	50	25.2	33	24.3	32	24.4
MCPA	0.56	40	24.2	52	27.0	48	24.2	38	26.2

Brookings 1985

	rate (kg/ha)	Lancer seeds	Lancer KW	Moore seeds	Moore KW	Noble seeds	Noble KW	Nodaway 70 seeds	Nodaway 70 KW
	0	55	28.1	60	27.2	49	30.1	42	30.5
2,4-D	0.28	42	29.1	58	27.9	44	30.3	32	33.7
	0.56	42	27.1	59	27.8	37	29.4	25	31.3
	0.84	33	26.4	57	27.6	30	29.3	21	31.3
MCPA	0.56	47	29.2	59	27.7	42	29.6	36	32.3

1 number of seeds per panicle
2 weight of 1000 kernels (gm)

Table 6 (con't). The number of seeds per panicle and 1000 kernel weights of oat varieties treated with 2,4-D amine and MCPA amine at Centerville and Brookings. Treatments were applied while the oats were in the 5½-to-6 leaf stage.

Centerville 1985

	rate (kg/ha)	Ogle seeds[1]	Ogle KW[2]	Porter seeds	Porter KW
	0	66	26.3	54	27.8
2,4-D	0.28	61	27.0	50	26.4
	0.56	54	25.2	50	26.5
	0.84	54	26.6	49	24.3
MCPA	0.56	55	27.8	50	25.8

Brookings 1985

	rate (kg/ha)	Ogle seeds	Ogle KW	Porter seeds	Porter KW
	0	58	29.9	54	26.6
2,4-D	0.28	54	29.9	54	27.6
	0.56	46	28.9	53	25.4
	0.84	46	29.7	58	23.9
MCPA	0.56	54	28.9	57	25.7

1 number of seeds per panicle
2 weight of 1000 kernels (gm)

Centerville added to the suppression of 1000 seed weights by inhibiting proper filling of the seeds. These effects on seed weight would explain the test weight reductions of oat varieties treated during the 5½-to-6 leaf stage.

The trend of 2,4-D's effect on seed weights is very evident. The seed weights increased when sprayed early without lodging; were suppressed somewhat with the addition of lodging; and were suppressed even more with the additional stress of being sprayed late. The number of seeds per panicle tends to decrease much more when oats are sprayed during the later stage as compared to the earlier. Lodging had no effect on the number of seeds per panicle. Figures 7 and 8 show the number of seeds per panicle and the seed weights for the varieties Chief and Lancer across the three rates of 2,4-D amine at all locations.

2,4-D also affects the amount of tillering by an oat plant. Derscheid (5) et. al, reported an increase in the number of panicles when oats were treated with 2,4-D ester. Aldrich (1), did a five year study on the effect of 2,4-D amine on oats grown in low and high fertility soils. He reported no significant difference in the number of tillers in 2,4-D treated oats grown on low fertility soils. However, in high fertility soils, the 2,4-D

Figure 7. Number of seeds per panicle and 1000 kernel weights of Chief when treated with three rates of 2,4-D amine at four locations. Oats at the Watertown location were in the 3-to-4 leaf stage when sprayed, while those at Brookings and Centerville were in the 5½-to-6 leaf stage. Results are expressed as a percent of the control.

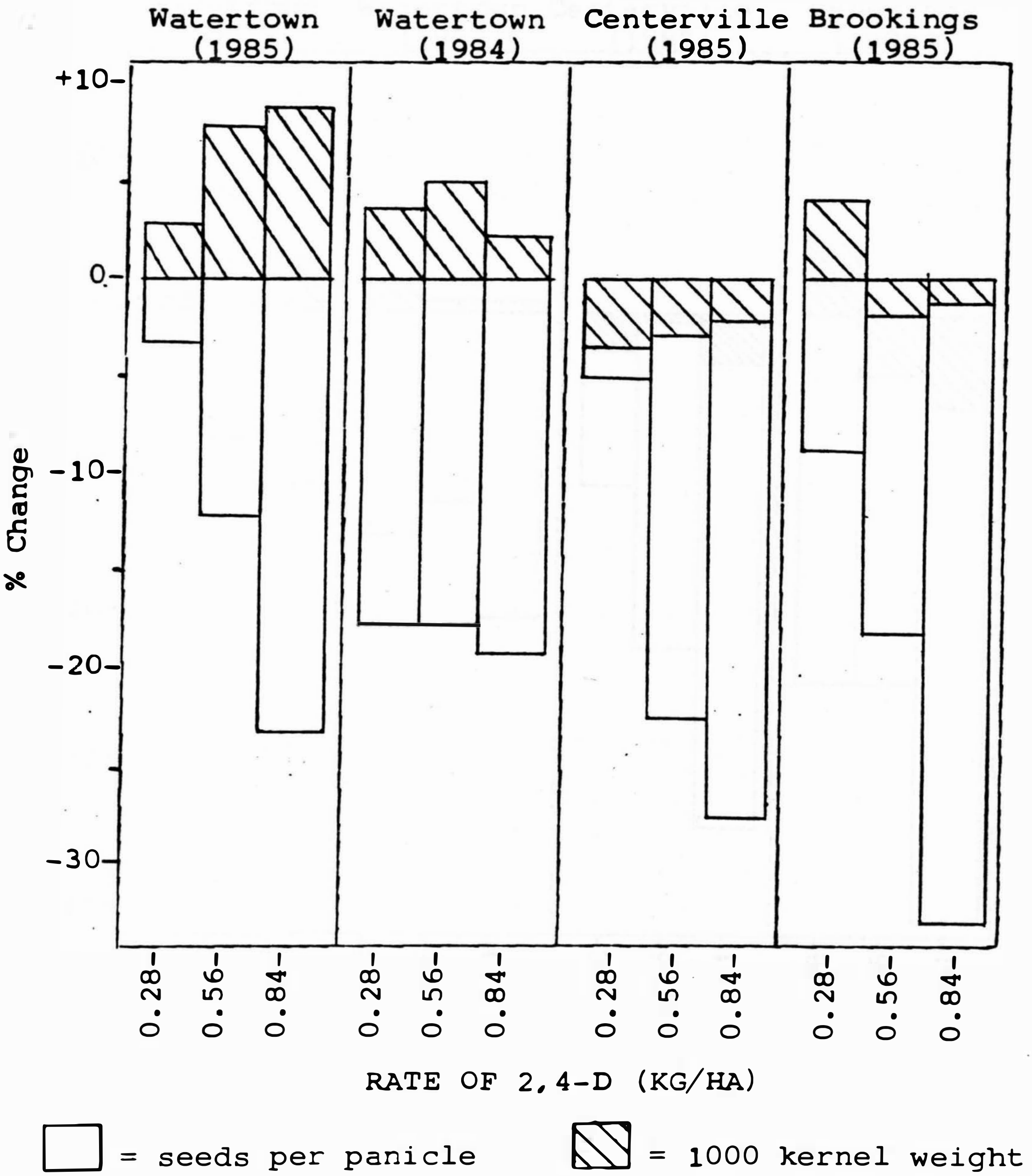
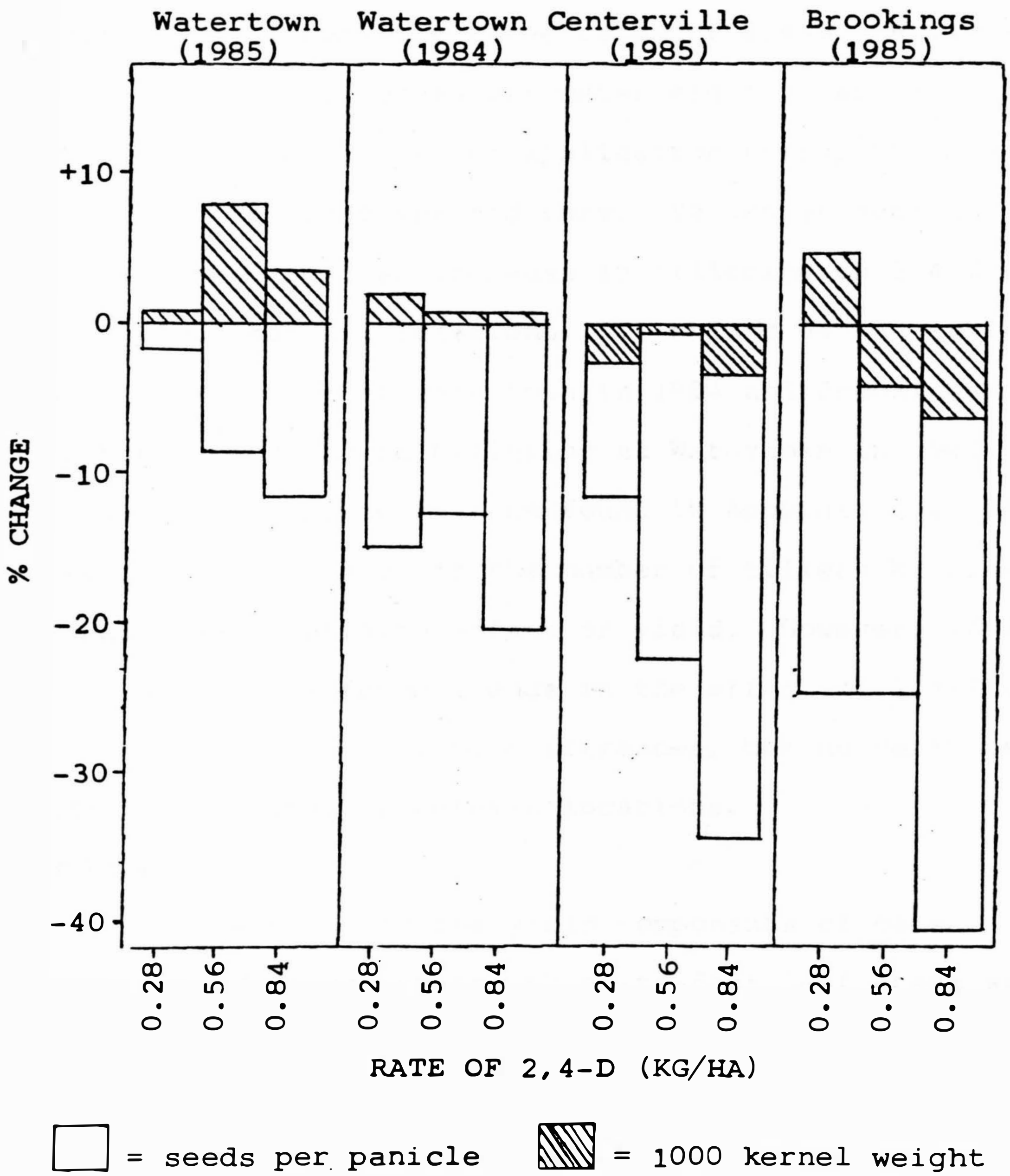


Figure 8. Number of seeds per panicle and 1000 kernel weights of Lancer when treated with three rates of 2,4-D at four locations. Oats at the Watertown location were in the 3-to-4 leaf stage when sprayed, while those at Brookings and Centerville were in the 5½-to-6 leaf stage. Results are expressed as a percent of the control.



treated plots had more tillers than the controls in all five years.

In our study, the number of grain producing panicles per meter of plot (tillering) did not exhibit a definite trend across the three rates of 2,4-D. While the actual number of stems per meter did not vary much between years, locations, or application times, the directions of the responses did vary. Varieties such as Lancer and Kelly had an increase in tillering on 2,4-D treated plots for all locations. Clintland 64 had an increase in tillering at Watertown in 1984 and Brookings in 1985, but a decrease in tillering at Watertown in 1985. All tillering responses can be found in Appendix 10. It was evident each change in the number of tillers by 2,4-D treatment had a definite effect on yield. However, while past studies (1,5) found trends in the effect of 2,4-D on tillering, this study found differences, but no definite trends across rates or between locations.

MCPA amine

The response by the yield components of oats treated with MCPA during the three-to-four leaf stage was similar to those treated during the 5½-to-6 leaf stage. The later spraying of MCPA caused a slightly greater decrease in the number of seeds per panicle than the early treatment, but differences were nonsignificant. The 1000 seed weights of the early treatments were not significantly diffent than those of the late treated oats. MCPA caused a reduction in the number of seeds per panicle for most varieties. There were, however, instances in which MCPA treatment resulted in an increase in the number of seeds per panicle. This increase occurred 20% of the time as compared to 5% for the same rate of 2,4-D across all locations. This may explain some of the slight increases in yields by some MCPA treated plots. A reduction in the number of seeds per panicle by MCPA treated plots was almost always less than that of the same rate of 2,4-D at the same location (Tables 5 and 6). It appears MCPA did not affect the panicle as drastically as 2,4-D. While a decrease in the number of seeds per panicle resulted in increased seed weights, the converse is also true. An increase in the number of seeds per panicle by MCPA treatment caused seed weights to decrease, possibly due to the oat plant having more seeds to fill. Seed weights of most varieties treated with MCPA during either the early or late leaf stage tended to increase slightly. However, Porter was an exception. It was previously reported MCPA caused significant yield reductions in Porter. The yield components indicate the seed weights of Porter were reduced at all four locations, regardless of the change in seed numbers. This may further suggest a possible susceptibility of Porter to MCPA.

Unlike 2,4-D, MCPA appears to have a definite trend in tillering. MCPA treated plots usually had more panicles per meter than the control plots. At Watertown in 1985, Clintland 64 and Noble both had decreases in tillering of (6%). At Brookings, both Noble (6%) and Lancer (11%) had a decrease in tillering. All other varieties at all locations responded with tiller numbers equal to or greater than the controls (Appendix 10). The combined effects of increasing tillers yet reducing seed numbers very little would explain why MCPA generally does not cause significant yield reductions, and often slightly increases yields.

Influence of Genetic Factors on Tolerance

No definite conclusions can be drawn from this study about the extent genetic factors influence oat tolerance to 2,4-D amine and MCPA amine. Results of this study indicate a greater relationship between time of panicle initiation and oat tolerance. This area is further discussed in the Suggestions section. While there is no doubt genetic factors do influence oat tolerance to 2,4-D to some extent, the degree was not determined in this study.

SUMMARY

<u>2,4-D amine applied at the three-to-four leaf stage</u>

1. The 0.28 kg ai/ha rate did not significantly reduce the yield of any variety. The 0.56 kg ai/ha rate only reduced the yield of Lancer. The yields of Garland, Kelly, Lancer and Nodaway 70 were significantly reduced at the 0.84 kg ai/ha rate.

2. As the rate of 2,4-D increased, the percent lodging increased for most varieties at most locations.

3. 2,4-D amine did not directly reduce the test weights of any variety. However, by causing an increase in lodging, it indirectly reduced test weight. As the percent lodging increased, the test weight generally decreased.

4. Applications of 2,4-D amine or MCPA amine at the three-to-four leaf stage or the 5½-to-6 leaf stages, had no significant effects on plant height, rust or heading date.

5. Applications of 2,4-D amine almost always caused a reduction in the number of seeds per panicle. When no lodging was present, and there was a reduction in the

number of seeds per panicle, 1000 seed weights increased (with the exception of Nodaway 70). When lodging was present, and the number of seeds per panicle was reduced, 1000 seed weights were usually very close to the control, with some slight increases and decreases.

6. 2,4-D amine treatment resulted in tillering responses which varied between treatments and locations within each variety.

5½-to-6 leaf 2,4-D amine treatment

7. Moore, Porter and Ogle were fairly tolerant to 2,4-D amine when treated at the 5½-to-6 leaf stage. All other varieties had significant yield reductions at all locations for all rates. Yield reductions were significantly greater with the 5½-to-6 leaf treatment than the three-to-four leaf treatment.

8. With the exception of Kelly, test weights appeared to be more dependent on the amount of lodging than the leaf stage of the oats when sprayed.

MCPA amine

9. The 0.56 kg ai/ha rate of MCPA applied during the three-to-four leaf stage, significantly reduced the

yields of Lancer and Porter in 1984 and 1985, and Kelly in 1985. The 5½-to-6 leaf treatments reduced the yield of Porter at Centerville in 1985 and Kelly in 1985 at both locations.

10. MCPA amine applications at the three-to-four leaf stage and the 5½-to-6 leaf stages almost always resulted in an increase in tillering.

11. MCPA generally caused a reduction in the number of seeds per panicle. There were no significant differences between the early and late MCPA treatments on the number of seeds per panicle or 1000 seed weights.

12. MCPA amine rarely caused an increase in lodging. As a result, there were few reductions in test weight in MCPA treated plots.

SUGGESTIONS

A two year study by Ross (23) may explain why some varieties are more susceptible to 2,4-D amine than others, particularly when treated after the five leaf stage. Ross' study involved fourteen oat varieties ranging from early to late in maturity. Every three days from emergence until heading, a sample of plants from each variety was dissected to determine shoot development. Near the time of panicle initiation extra samples were taken to accurately determine that date. Panicle initiation is the transition period when the plant changes from its vegatative phase to the reproductive phase. During this period, the growing point differentiates, and the inflorescence and its parts begin to develop. In the first year of his study, the period from planting to panicle initiation ranged from 30 days for the earliest variety, to 38 days for the latest variety, a difference of 8 days. In the second year, the range was from 22 to 30 days, also a difference of 8 days. The actual number of days from planting to panicle initiation will vary depending on day length, temperature and other environmental factors. However, 8 days appeared to be an average range for panicle initiation between the early and late varieties in his study. Ross also stated "rate of leaf development was nearly identical among all varieties throughout early growth, but leaf numbers at time of panicle initiation were markedly lower for early varieties and higher for later ones". Leaf numbers at panicle initiation ranged from 3.1 leaves for the earliest variety to 5.2 for the latest. The average for all varieties was 4 leaves. There was not much difference between most early and midseason varieties, however, at panicle initiation, the late varieties all had from one to two more leaves than the early and midseason varieties. This means when all varieties were in the four leaf stage, the early ones may have already began panicle initiation while the late ones had not. Ross also reported varieties do not always begin panicle initiation in the same sequence as they head. In his study, an early variety, 60 Day, began panicle initiation 2 days after the midseason line Ill. 30-2088, yet headed 2 days before it. Thus, maturity classifications based on heading date cannot always be applied to panicle initiation.

Ross' findings may explain many of the results of this study. In our study, the later maturing varieties (Moore and Porter) were consistantly the most tolerant to 2,4-D amine, while the three earliest varieties (Nodaway 70, Kelly and Lancer) were often the most susceptible. This is according to the effect 2,4-D had on the yield components and not strictly yield, since tillering can alter the effect of 2,4-D on yield.

2,4-D is a herbicide which concentrates in areas of high meristematic activity. Once an oat plant reaches panicle initiation, the growing point becomes a meristematic area in which 2,4-D would concentrate. Therefore, those varieties which initiate panicles first should be more susceptible to 2,4-D at an earlier leaf stage. This may be why the early varieties in our study were the most susceptible, particularly at the 5½-to-6 leaf stage. Conversely, the late varieties were most tolerant. It appears all varieties, except Moore and Porter, began panicle initiation by the 5½-to-6 leaf stage. The early varieties, which seemed to begin panicle initiation near the three-to-four leaf stage, were the most injured as a result of the 5½-to-6 leaf treatment. This is possibly due to their panicles being more developed than the midseason and late varieties. As Ross (23) reported, the early varieties began panicle initiation about 2 leaf stages or 8 days sooner than the late varieties.

While the early varieties were most susceptible, and the late varieties most tolerant to 2,4-D amine, the response of the midseason varieties varied. Lancer, which is an early midseason variety, was the most susceptible of the midseason varieties, while Ogle was the most tolerant. Ross (23), reported panicle initiation varied up to 2 days between the midseason varieties in his study. Therefore, it may be Lancer is reaching panicle initiation before Ogle and thus would be more susceptible to 2,4-D.

The theory that panicle initiation is the major determining factor in oat tolerance to 2,4-D may explain certain visual injuries in this study. Panicles within a 2,4-D treated plot ranged in shape from normal, healthy looking panicles (similar to those in the check plots) to very compact panicles with obvious seed number reductions. Shands and Cisar (25), reported panicle initiation begins 2 to 4 days later in the second tiller than in the first. It may be the panicles of the later tillers had not initiated at the time of treatment, while the main culm and possibly the first tiller had. Thus, the later tillers would be in a tolerant stage of development, while the main culm and first tiller would be in a susceptible stage. If this is the case, it would explain why panicle injury varied within each plot, and why plots treated in the 5½-to-6 leaf stage had a much higher percent of compact panicles.

The actual time of panicle initiation of each variety relative to the others is unknown. The true relationship between time of panicle initiation and oat tolerance to 2,4-D is also uncertain. A better understanding of these would be gained through further research combining oat plant dissection (similar to Ross' (23)), with herbicide applications at various leaf stages. Since the number of days from planting to panicle initiation varies depending on day length and temperature, it would be desirable to test the varieties under more than one environmental condition. It would also be advantageous to include a wide range of maturity classifications and pedigrees.

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Appendix 1. Soil analysis from the 1985 plots at the Watertown and Brookings locations. The soil was not analyzed at Watertown in 1984 or Centerville in 1985. Sample depth was 0-20.3 cm (0-8 inches).

	Watertown	Brookings
NO_3-N (ppm)	5	12
NO_3-N (lbs/A)	74[a]	28
Organic matter (%)	2.6	3.2
Phosphorus (lbs/A)	52	139
Potassium (lbs/A)	310	390
pH	6.5	7.1
1:1 Salts (mmho/cm)	0.2	0.7

a the soil at Watertown was analyzed as having 9 lbs/A NO_3-N, however nitrogen fertilizer was applied to bring the NO_3-N up to 74 lbs/A.

Appendix 2. The climatic conditions at time of application of 2,4-D amine and MCPA amine for all locations.

		Planting Dates	Date of Application	Temperature C	Relative Humidity %	Wind Speed mph	Cloud Cover
1984	Watertown	4/25/84	6/5/84	15.6	70	5	clear
	Brookings	4/12/85	5/13/85	10.0	70	0-2	cloudy
1985	Watertown	4/18/85	5/21/85	15.6	50	2-5	clear
	Centerville	4/11/85	5/12/85	12.8	50	0-2	clear

Appendix 3. The yield (mean gm/plot) of oat varieties treated during the three-to-four leaf stage with 2,4-D amine and MCPA amine.[1]

	rate (kg/ha)	Burnett	Chief	Clintland 64	Garland	Kelly
			Watertown 1984			
	0	768a	667b	716b	722a	---
2,4-D	0.28	773a	672b	760a	680ab	---
	0.56	781a	723a	762a	710a	---
	0.84	719b	669b	715b	654b	---
MCPA	0.56	794a	701ab	753ab	698a	---
			Watertown 1985			
	0	624a	594ab	609a	---	652a
2,4-D	0.28	577a	613a	609a	---	625ab
	0.56	630a	597ab	531b	---	618ab
	0.84	591a	570b	537ab	---	607b
MCPA	0.56	593a	624a	577ab	---	607b

1 within varieties and years means followed by different letters are significantly different when analyzed by Waller-Duncan proceedure.

Appendix 3 (con't).[1]

Watertown 1984

	rate (kg/ha)	Lancer	Moore	Noble	Nodaway 70[2]	Ogle	Porter
	0	856a	860b	663a	---	829a	854a
2,4-D	0.28	808ab	869b	685a	---	829a	899a
	0.56	795b	910a	653a	---	841a	888a
	0.84	784b	908a	624a	---	843a	852a
MCPA	0.56	812ab	896ab	615a	---	833a	743b

Watertown 1985

	rate (kg/ha)	Lancer	Moore	Noble	Nodaway 70	Ogle	Porter
	0	646a	711a	490a	615a	619a	642a
2,4-D	0.28	627ab	720a	500a	608a	605a	612a
	0.56	587bc	719a	483a	630a	632a	655a
	0.84	561c	718a	469a	573b	619a	649a
MCPA	0.56	588bc	717a	512a	598ab	625a	604a

1 within varieties and years means followed by different letters are significantly different when analyzed by Waller-Duncan proceedure.

2 Nodaway 70 plots at Watertown in 1984 were damaged by ground squirrels.

Appendix 4. The yield (mean gm/plot) of oat varieties treated during the 5½-to-6 leaf stage with 2,4-D amine and MCPA amine.[1]

Centerville

	rate (kg/ha)	Burnett	Chief	Clintland 64	Kelly	Lancer
	0	948a	989a	878a	957a	933a
2,4-D	0.28	726b	861b	786ab	726bc	838bc
	0.56	647b	751c	695b	738bc	814c
	0.84	645b	718c	599c	679c	697d
MCPA	0.56	889a	912ab	840a	841ab	905ab

Brookings

	rate (kg/ha)	Burnett	Chief	Clintland 64	Kelly	Lancer
	0	752a	815a	735a	868a	890a
2,4-D	0.28	667b	727bc	704a	710c	820b
	0.56	566c	641cd	573b	643d	722c
	0.84	521c	611d	557b	593d	657d
MCPA	0.56	735a	783ab	745a	808b	863ab

1 within varieties and locations means followed by different letters are significantly different when analyzed by the Waller-Duncan proceedure.

Appendix 4 (con't).[1]

Centerville

	rate (kg/ha)	Moore	Noble	Nodaway 70	Ogle	Porter
	0	1040b	910a	927a	1004a	1050a
2,4-D	0.28	1039b	859ab	738b	1003a	990ab
	0.56	1030b	817b	702b	1018a	915ab
	0.84	1011b	716c	660b	926b	840b
MCPA	0.56	1138a	877ab	849a	1009a	984a

Brookings

	rate (kg/ha)	Moore	Noble	Nodaway 70	Ogle	Porter
	0	1009a	714a	682ab	825a	751a
2,4-D	0.28	920bc	677ab	632b	802ab	795a
	0.56	903bc	584c	547c	752ab	746a
	0.84	870c	470d	484c	722b	713a
MCPA	0.56	961ab	647b	715a	796ab	789a

1 within varieties and locations means followed by different letters are significantly different when analyzed by the Waller-Duncan proceedure.

Appendix 5. Temperature and precipitation data at the Watertown, Centerville and Brookings locations during the 1984 and 1985 growing seasons.

		Monthly Average Temperature (F)		Monthly Precipitation (inches)	
		1984	1985	1984	1985
Watertown	April	43.8	49.6	3.03	1.99
	May	53.9	61.3	2.30	1.27
	June	65.9	62.5	5.28	1.54
	July	71.6	70.1	2.38	3.42
Centerville	April	----	53.0	----	4.93
	May	----	63.5	----	5.53
	June	----	66.3	----	4.42
	July	----	71.3	----	0.54
Brookings	April	----	48.4	----	2.00
	May	----	59.5	----	3.40
	June	----	61.5	----	0.91
	July	----	68.3	----	1.56

Appendix 6. The effect of 2,4-D amine and MCPA amine on the test weight of oat varieties treated during the 5½-to-6 leaf growth stage.[1]

Centerville

	rate (kg/ha)	Burnett TW[2]	Chief TW	Clintland 64 TW	Kelly TW	Lancer TW
	0	33.7a	33.9a	34.4a	36.8a	33.8a
2,4-D	0.28	32.0a	33.6ab	32.9b	35.3ab	33.4a
	0.56	31.9a	32.9abc	33.1ab	34.7bc	32.6ab
	0.84	31.0a	32.4c	32.0b	33.5c	31.4b
MCPA	0.56	32.3a	33.6ab	33.2ab	35.2abc	33.4a

Brookings

	rate (kg/ha)	Burnett TW	Chief TW	Clintland 64 TW	Kelly TW	Lancer TW
	0	32.3a	33.0ab	32.4a	37.4a	34.2a
2,4-D	0.28	31.9ab	34.0a	33.0a	36.8a	33.2ab
	0.56	30.3b	32.5ab	31.9a	34.0b	32.0ab
	0.84	30.9ab	32.1b	31.3a	33.3b	31.2b
MCPA	0.56	31.3ab	32.6ab	32.7a	36.9a	32.7ab

1 within varieties and locations means followed by different letters are significantly different when analyzed by the Waller-Duncan proceedure.

2 test weight (pounds/bushel)

Appendix 6 (con't).[1]

Centerville

	rate (kg/ha)	Moore TW[2]	Noble TW	Nodaway 70 TW	Ogle TW	Porter TW
	0	34.9a	33.6a	35.1a	31.2a	33.8a
2,4-D	0.28	33.9ab	33.6ab	33.9ab	30.8ab	31.2ab
	0.56	34.3ab	33.7a	33.7ab	30.7ab	31.9ab
	0.84	33.4b	31.5c	32.9b	29.7c	29.9b
MCPA	0.56	34.8a	32.3bc	33.5ab	30.0bc	31.9ab

Brookings

	rate (kg/ha)	Moore TW	Noble TW	Nodaway 70 TW	Ogle TW	Porter TW
	0	35.4a	31.1a	33.5ab	30.9ab	30.9a
2,4-D	0.28	35.5a	31.8a	34.5a	31.5a	32.2a
	0.56	34.4a	30.9a	32.7ab	29.9b	29.1b
	0.84	34.1a	29.4a	31.0b	30.6ab	28.0b
MCPA	0.56	35.6a	30.5a	33.2ab	30.5ab	30.4a

1 within varieties and locations means followed by different letters are significantly different when analyzed by the Waller-Duncan proceedure.

2 test weight (pounds/bushel)

Appendix 7. The effect of 2,4-D amine and MCPA amine on the height of oat varieties. The Watertown location in 1984 and 1985 was treated while the oats were in the 3-to-4 leaf stage. Centerville and Brookings were treated during the 5½-to-6 leaf stage. Results are expressed as the difference in height (cm) from the controls.

	Watertown 1984				Watertown 1985			
	2,4-D (kg/ha)			MCPA	2,4-D (kg/ha)			MCPA
	0.28	0.56	0.84	0.56	0.28	0.56	0.84	0.56
Burnett	-1.0	-0.3	-1.0	-1.0	-1.0	-0.8	-2.0	-0.8
Chief	0.8	0.8	4.3	-3.3	-1.3	-1.8	-2.8	-4.5
Clintland 64	2.3	3.0	3.0	1.0	0.3	0.0	-0.8	2.3
Garland	1.5	3.3	0.0	-0.8	---	---	---	---
Kelly	---	---	---	---	4.3	1.5	3.8	2.5
Lancer	1.8	2.3	-0.5	-2.0	1.5	0.3	1.8	0.8
Moore	2.8	4.3	3.3	1.8	3.5	0.0	-0.3	0.8
Noble	-1.5	0.0	-0.5	-5.5	0.5	0.5	0.8	-0.5
Nodaway 70	-1.0	-0.5	0.0	-3.8	0.3	0.8	-1.3	-0.8
Ogle	-1.3	-0.5	-0.3	-2.8	1.8	2.0	4.0	3.0
Porter	0.3	0.8	1.8	-7.0	-3.5	1.0	-1.3	-2.3

	Centerville				Brookings			
Burnett	0.3	-0.8	2.5	0.8	1.8	1.5	2.0	1.3
Chief	3.0	2.8	0.5	2.0	0.0	2.0	1.3	1.5
Clintland 64	2.0	0.0	0.3	0.3	1.0	1.8	2.0	3.3
Kelly	1.8	0.5	0.0	-0.8	0.5	0.5	-2.0	-2.0
Lancer	5.0	2.5	2.0	-0.8	0.0	-1.0	2.3	-0.5
Moore	1.3	3.0	1.3	-1.0	0.8	1.3	-1.0	-0.5
Noble	5.5	3.3	6.0	0.8	1.5	3.0	2.3	1.8
Nodaway 70	-1.3	-0.8	0.0	-0.3	-0.5	-1.3	0.8	-0.8
Ogle	1.8	3.5	2.0	0.3	2.5	7.3	3.5	0.5
Porter	0.5	0.0	0.5	-1.5	2.8	3.3	1.3	2.0

Appendix 8. Crown rust readings of oat varieties sprayed during the 5½-to-6 leaf stage with 2,4-D amine and MCPA amine. Rust readings are expressed as the percent of the oat leaf surface area covered by rust pustules.[1]

Centerville

	Rate of 2,4-D (kg/ha)				MCPA (kg/ha)
	control	0.28	0.56	0.84	0.56
Burnett	4	9	4	3	8
Chief	2	9	7	4	3
Clintland 64	4	7	8	10	5
Kelly	0	1	0	1	0
Lancer	4	4	4	7	5
Moore	0	2	1	1	1
Noble	12	11	11	12	10
Nodaway 70	4	11	7	9	6
Ogle	4	5	7	3	7
Porter	6	5	4	6	9
Average	4	6	5	6	5

Brookings

	control	0.28	0.56	0.84	0.56
Burnett	24	35	35	32	24
Chief	17	24	32	34	17
Clintland 64	22	29	37	31	31
Kelly	6	6	9	9	7
Lancer	20	19	25	21	20
Moore	11	14	17	16	16
Noble	30	31	40	41	25
Nodaway 70	36	34	44	36	39
Ogle	21	25	25	25	27
Porter	24	19	17	22	19
Average	21	24	28	27	23

1 all differences are nonsignificant.

Appendix 9. The effect of 2,4-D amine and MCPA amine on the heading date of oat varieties sprayed during the 5½-to-6 leaf stage. Responses are expressed as the difference in days from the control.[1]

Brookings

	Rate of 2,4-D (kg/ha)			MCPA (kg/ha)
	0.28	0.56	0.84	0.56
Burnett	0.5	0.0	0.0	0.0
Chief	0.5	0.3	0.5	0.3
Clintland 64	0.0	0.3	0.5	0.3
Kelly	0.0	0.3	0.5	0.5
Lancer	0.8	0.3	0.5	0.0
Moore	0.0	0.5	-0.8	0.5
Noble	0.5	0.0	-0.3	-0.5
Nodaway 70	0.0	0.8	0.3	0.3
Ogle	0.8	0.5	0.8	-0.3
Porter	0.0	1.0	1.5	0.5
Average	0.3	0.4	0.4	0.2

1 all differences are nonsignificant

Appendix 10. The effect of 2,4-D amine and MCPA amine on the number of grain producing panicles per meter of plot (tillering). Oats at Watertown were sprayed during the 3-to-4 leaf stage, while Brookings was in the 5½-to-6 leaf stage.

Watertown 1984

	Rate of 2,4-D (kg/ha)				MCPA (kg/ha)
	control	0.28	0.56	0.84	0.56
Burnett	102	123	125	125	122
Chief	69	91	96	99	99
Clintland 64	103	121	115	106	114
Garland	120	98	120	101	119
Lancer	106	115	106	114	105
Moore	102	113	120	118	109
Noble	90	111	110	98	99
Nodaway 70	119	110	119	111	126
Ogle	105	114	107	117	110
Porter	106	95	108	97	104

Watertown 1985

Burnett	105	99	105	109	106
Chief	98	94	98	104	98
Clintland 64	105	95	101	98	98
Kelly	112	122	122	122	123
Lancer	112	119	121	123	114
Moore	108	117	107	114	113
Noble	117	108	116	115	111
Nodaway 70	107	112	112	114	106
Ogle	97	94	94	94	101
Porter	96	96	105	93	98

Brookings

Burnett	102	115	106	90	119
Chief	103	97	107	110	103
Clintland 64	92	109	113	113	120
Kelly	115	115	141	130	136
Lancer	121	124	151	133	106
Moore	123	108	124	125	122
Noble	110	104	121	116	103
Nodaway 70	121	110	124	124	126
Ogle	96	86	98	95	108
Porter	97	106	110	115	115

Appendix 11. Analysis of variance for all yield data at all four locations.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Locations	3	6397582.25	717.79	**
Varieties	8	4336834.33	182.47	**
LxV	24	1015344.74	14.24	**
Treatments	4	1071589.44	90.17	**
LxT	12	794609.56	22.29	**
VxT	32	331927.71	3.49	**
LxVxT	96	318921.88	1.12	n.s.
Replications	12	438051.64	12.29	**
VxR	96	256333.91	0.90	n.s.
TxR	48	530032.11	3.72	**
TOTAL	335			

Tests of hypotheses using the ANOVA MS for Replications as an error term.

Source	DF	ANOVA SS	F Value	
Locations	3	6397582.25	58.42	**

Tests of hypotheses using the ANOVA MS for LxV as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	8	4336834.33	12.81	**

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
LxV	24	1015344.74	15.84	**

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 11 (con't).

Tests of hypotheses using the ANOVA MS for LxT as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	1071589.44	4.05	*

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
LxT	12	794609.56	6.00	**

Tests of hypotheses using the ANOVA MS for LxVxT as an error term.

Source	DF	ANOVA SS	F Value	
VxT	32	331927.71	3.12	**

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 12. Analysis of variance for all test weight data at all four locations.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Locations	3	59222.02	509.36	**
Varieties	8	34212.89	110.35	**
LxV	24	24410.47	26.24	**
Treatments	4	8298.19	53.53	**
LxT	12	4870.89	10.47	**
VxT	32	1614.91	1.30	n.s.
LxVxT	96	3189.11	0.86	n.s.
Replications	12	6312.28	13.57	**
VxR	96	2518.92	0.68	n.s.
TxR	48	15607.05	8.39	**
TOTAL	335			

Tests of hypotheses using the ANOVA MS for Replications as an error term.

Source	DF	ANOVA SS	F Value	
Locations	3	59222.03	37.53	**

Tests of hypotheses using the ANOVA MS for LxV as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	8	34212.89	4.20	**

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
LxV	24	24410.47	38.75	**

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 12 (con't).

Tests of hypotheses using the ANOVA MS for LxT as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	8298.19	5.11	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA MS	F Value	
LxT	12	4870.89	1.25	n.s.

Tests of hypotheses using the ANOVA MS for VxTxR as an error term.

Source	DF	ANOVA MS	F Value	
VxT	32	1614.91	1.52	n.s.

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 13. Analysis of variance for all lodging data at all four locations.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Locations	3	80581.37	206.37	**
Varieties	8	78291.89	75.19	**
LxV	24	37962.12	12.15	**
Treatments	4	51608.31	99.13	**
LxT	12	29576.22	18.94	**
VxT	32	14315.91	3.44	**
LxVxT	96	23046.35	1.84	**
Replications	12	5047.88	3.23	**
VxR	96	12727.37	1.02	n.s.
TxR	48	26594.76	4.26	**
TOTAL	335			

Tests of hypotheses using the ANOVA MS for Replications as an error term.

Source	DF	ANOVA SS	F Value	
Locations	3	80581.37	63.85	**

Tests of hypotheses using the ANOVA MS for LxV as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	8	78291.89	6.19	**

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
LxV	24	37962.12	11.93	**

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 13 (con't).

Tests of hypotheses using the ANOVA MS for LxT as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	51608.31	5.23	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
LxT	12	29576.22	4.45	**

Tests of hypotheses using the ANOVA MS for LxVxT as an error term.

Source	DF	ANOVA SS	F Value	
VxT	32	14315.91	1.86	**

*,** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 14. Analysis of variance for the number of seeds per panicle at Watertown in 1985.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Varieties	9	145693.36	132.13	**
Treatments	4	12913.22	26.35	**
VxT	36	19879.40	4.51	**
Replications	3	6635.82	18.05	**
VxR	27	15031.66	4.54	**
TxR	12	7668.83	5.22	**
VxTxR	108	38552.52	2.91	**
TOTAL	199			

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	145693.36	29.08	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	12913.22	5.05	**

Tests of hypotheses using the ANOVA MS for VxTxR as an error term.

Source	DF	ANOVA	F Value	
VxT	36	19879.40	1.55	*

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 15. Analysis of variance for the 1000 kernel weight of oats at Watertown in 1985.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Varieties	9	1.5172	14.54	**
Treatments	4	0.3197	6.89	**
VxT	36	0.5069	1.21	n.s.
Replications	3	0.0439	1.26	n.s.
VxR	27	0.3748	1.20	n.s.
TxR	12	1.2872	9.25	**
TOTAL	91			

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	1.5172	12.14	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	0.3197	0.75	n.s.

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 16. Analysis of variance for the number of seeds per panicle at Watertown in 1984.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Varieties	9	103133.42	115.66	**
Treatments	4	17506.17	44.17	**
VxT	36	13892.59	3.89	**
Replications	3	6494.85	21.85	**
VxR	27	10392.29	3.88	**
TxR	12	5972.42	5.02	**
VxTxR	108	31938.02	2.98	**
TOTAL	199			

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	103133.42	29.77	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	17506.17	8.79	**

Tests of hypotheses using the ANOVA MS for VxTxR as an error term.

Source	DF	ANOVA SS	F Value	
VxT	36	13892.59	1.30	n.s.

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 17. Analysis of variance for the 1000 kernel weight of oats at Watertown in 1984.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Varieties	9	9.6599	119.56	**
Treatments	4	0.1237	3.45	**
VxT	36	0.4185	1.30	n.s.
Replications	3	0.2348	8.72	**
VxR	27	0.3356	1.38	n.s.
TxR	12	0.2823	2.62	**
TOTAL	91			

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	9.6599	86.35	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	0.1237	1.32	n.s.

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 18. Analysis of variance for the number of seeds per panicle at Centerville in 1985.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Varieties	9	257755.47	253.27	**
Treatments	4	72073.29	159.35	**
VxT	36	19409.93	4.77	**
Replications	3	1050.09	3.10	*
VxR	27	16287.25	5.33	**
TxR	12	10913.02	8.04	**
VxTxR	108	28739.26	2.35	**
TOTAL	199			

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	257755.47	47.48	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	72073.29	19.81	**

Tests of hypotheses using the ANOVA MS for VxTxR as an error term.

Source	DF	ANOVA SS	F Value	
VxT	36	19409.93	2.03	**

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 19. Analysis of variance for the 1000 kernel weights of oats at Centerville in 1985.

Source of Variation	Degrees of Freedom	ANOVA SS	F Value	
Varieties	9	2.5996	13.63	**
Treatments	4	0.1771	2.09	n.s.
VxT	36	1.2072	1.58	*
Replications	3	2.3335	36.70	**
VxR	27	0.6124	1.07	n.s.
TxR	12	1.2911	5.08	**
TOTAL	91			

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	2.5997	12.73	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	0.1771	0.41	n.s.

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.

Appendix 20. Analysis of variance for the number of seeds per panicle at Brookings in 1985.

Source of Variation	Degrees of Freedom	ANOVA SS
Varieties	9	6389404.32
Treatments	4	2077512.57
VxT	36	720682.73
Replications	3	127674.36
VxR	27	144044.84
TxR	12	445558.59
VxTxR	108	761127.71
TOTAL	199	

Tests of hypotheses using the ANOVA MS for VxR as an error term.

Source	DF	ANOVA SS	F Value	
Varieties	9	6389404.32	133.07	**

Tests of hypotheses using the ANOVA MS for TxR as an error term.

Source	DF	ANOVA SS	F Value	
Treatments	4	2077512.57	13.99	**

Tests of hypotheses using the ANOVA MS for VxTxR as an error term.

Source	DF	ANOVA SS	F Value	
VxT	36	720682.73	2.84	**

*, ** significant at 5 and 1% level, respectively.

n.s. not significantly different.